Multi-scale analysis on NDVI and topographical factors of Wuyi mountain reserve area using wavelet method

Qiu Bingwen*, Su Zanyou, and Chen Chongcheng,
Key Laboratory of Spatial Data Mining and Information Sharing of Ministry of Education, Spatial Information Research Center of Fujian Province, Fuzhou University, Fuzhou 350002, Fujian Province, China
*qiubingwen@fzu.edu.cn

Bela Markus
University of West Hungary
8002 Székesfehérvár, P.O.B. 52,
Hungary

Abstract: **Wuyi Mountain Reserve area is the one of the few reserve Areas for both world biosphere, cultural and natural heritage in China. This paper addresses the scale dependency problem of vegetation-topography relations of Wuyi Mountain Reserve area. The wavelet transform was applied to analyze the multi-scale correlations between Normalized Difference Vegetation Index (NDVI) and several topographic factors (DEM, slope and aspect). The results of wavelet coefficient variograms show that spatial patterns of NDVI and Topographical indicator both exhibit two dominant scales. The fact of nearly synchronous scale domain, especially in small scale domain, suggests that tightly-coupled relationship exists between NDVI and DEM. Results of multi-scale correlation relationships among NDVI and geographical factors suggest that the correlation is scale-dependent, i.e. different scales have different coefficients among the factors. The coefficient values between NDVI and topographical factors are larger in coarser scales than those in finer scales, which suggest that topographical factors have important roles on controlling NDVI patterns in larger scale. The relationship between NDVI and slope, aspect exhibit complicated variation with spatial scales. This study may improve the understanding of the multi-scale role that topography plays in the formation of vegetation patterns in mountainous areas and also suggest that wavelet transform is useful in exploring the multi-scale pattern of natural resources.**

Key words: Wuyi Mountain Reserve area; multi-scale analysis; NDVI; DEM

I. INTRODUCTION

Since topography is believed to pose a stable control on vegetation in mountainous regions (Franklin, 1995), its abundant data and analysis techniques can be applied to exploring vegetation distribution patterns. Quantitative information of topography–vegetation relationships may be obtained by exploring statistical correlations between topographic properties and remotely sensed high resolution vegetation indices, typically multi-scale correlation analysis based on a series of exploratory statistical techniques(A. Nelson, 2007). Those studies provide several new insights into the topography–vegetation relationships(Brown et al., 1994; Walsh et al., 1997, 1999; Deng, et al., 2007), revealing the topographic role in vegetation patterns along with scale. But the multi-scale statistical correlation method needs reproduction of multiple resolution data based on the original database and it's time-consuming. With the nature of multi-scale analysis, methods based on wavelet analysis can overcome this shortcoming.

II. STUDY AREA AND DATABASE

A. Study Area

Wuyi Mountain Reserve area is the only reserve Area for world biosphere, cultural and natural heritage of China. It is located between latitude 27°33 -27°54′ N and longitude 117°27′-117°51′E, southeast of China. Total area is approximately 56527hm^2. It has the largest and most completely preserved sub-tropical forest ecosystems in southeast of China. The climate is characterized as semi-tropic monsoon zone. The relative high peaks in the northeast part become a natural barrier. A kind of micro climate which characterized as low temperatures, large precipitation, high humidity, long fog days and significant variation in vertical has been formed.

B. Database

Landsat Enhanced Thematic Map plus cloud-free images, acquired on October 21, 2001, was used to represent the range of vegetation greenness and moisture in Wuyi mountain reserve area. NDVI was calculated using the ETM scaled band 4 and 3 reflectance data: NDVI= (TM4-TM3)/(TM4+TM3). The calculated NDVI values from the above equation were linearly transformed to 0 ~ 255 (Fig. 1). Topographic data was gained from 50,000 DEM data from Bureau of Surveying and Mapping of Fujian Province (Fig. 1).

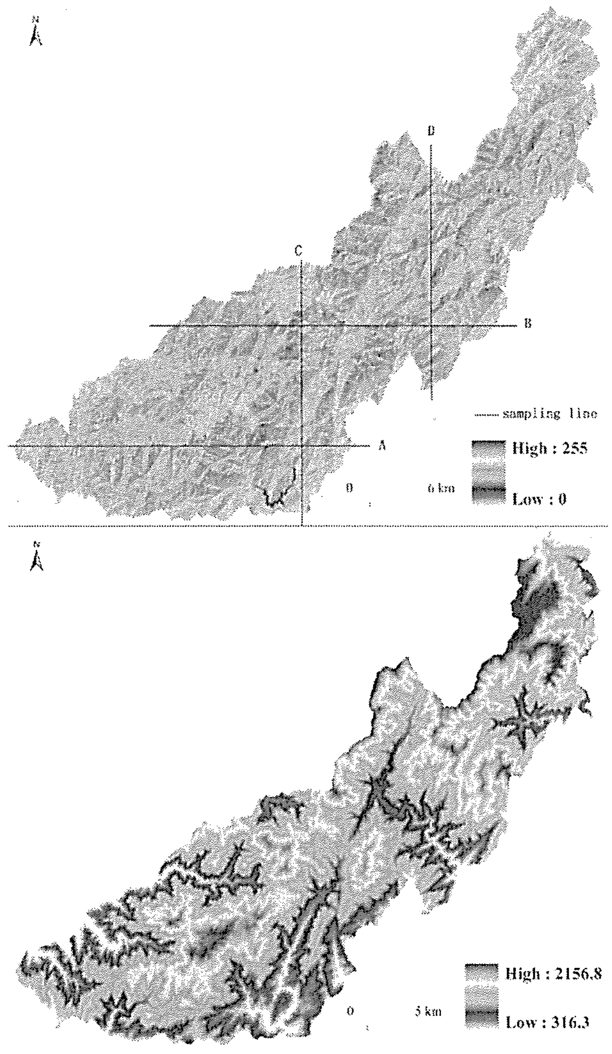

Figure 1. Distribution map of NDVI (top) and DEM (down)

III. METHODOLOGY

A. 3.1. Data Processing

Topographic factor (slope and aspect) were calculated from DEM using ARCGIS9.0 software. Four sampling lines were set along latitude line 27°37′, 27°42′ and longitude 117°37′, 117°43′ respectively (Fig.1, sampling line A,B,C,D).

B. 3.2. Wavelet transform

Basal wavelet was selected to multiple with the function under analysis in order to get the wavelet coefficient and wavelet variance based on the square of corresponding coefficient. The equations were as followings:

$$\sigma(2^j) = \sqrt{\sum_{y=1}^{M_j}\sum_{x=1}^{N_j}\left[C(2^j,x,y)-\mu(2^j)\right]\Big/(M_j * N_j)} \quad (1)$$

$$\mu(2^j) = \sum_{y=1}^{M_j}\sum_{x=1}^{N_j} C(2^j,x,y)/(M_j * N_j) \quad (2)$$

Where $C(2^j, x, y)$ is the wavelet coefficient at scale 2^j, M_j、N_j is the corresponding dimension, $\mu(2^j)$、$\sigma(2^j)$ is average wavelet coefficient and wavelet Variance.

Wavelet db6 were adopted as the basal wavelet and the decomposing level is 8. Wavelet variance, low-frequency and high-frequency coefficient at eight different scales were gotten based on wavelet transform and multi-scale correlation analysis was conducted.

IV. RESULTS

A. Multi-Scale Distribution Pattern of NDVI

Wavelet coefficient variograms of NDVI (Fig. 2) exhibit similar shape and trend in two latitude and two longitude lines, each with two scale space: spatial patterns of NDVI exhibit two dominant scales of 350-750m, 2500-3000m in longitude and 500-700m, 2500m or 4000m in latitude direction respectively. Total variation along longitude 27°37′N and latitude 117°43′E is relatively larger than that of the other two lines. From the vegetation they covered, it showed that those two lines occupied more diversity and more fragmentation.

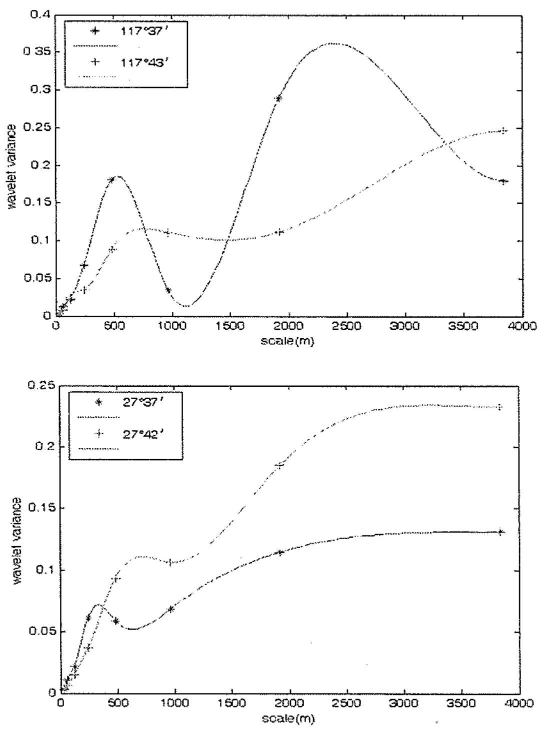

Figure 2. Multi-scale pattern of NDVI along longitude and latitude direction

B. *Multi-Scale Distribution Pattern of DEM*

Similar to NDVI, the results of wavelet coefficient variograms of DEM also exhibits two clear scale patterns: one small dominant scale at 350m and the other large one at 1200m (south), 1500m (north) in latitude respectively; one small dominant scale at 350-500m and the other large one at 2200m (west) and 4000m (east) in longitude respectively.

Both the wavelet coefficients of NDVI and DEM exhibit two clear scale spaces and the large one show large variation. The fact of synchronous variance peak of 2200m in 117°43 ′ E suggests that tightly-coupled relationship exists between NDVI and DEM.

Multi-scale correlation relationships among NDVI and geographical factors were also examined using wavelet transform at both high and low frequency (table 1). Results suggest that the correlation is scale-dependent. The coefficient values between NDVI and topographical factors such as elevation, aspect and slope are larger in coarser scales than those in finer scales at low frequency, which suggest that topographical factors have important roles on controlling NDVI patterns in a larger scale.

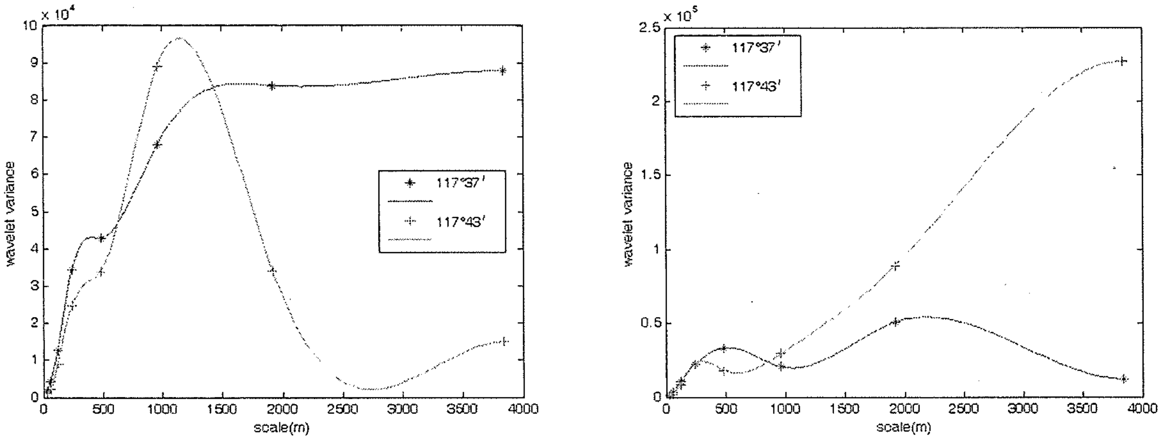

Figure 3. Multi-scale pattern of DEM along longitude and latitude direction

TABLE I. MULTI-SCALE CORRELATIONSHIP OF NDVI AND TOPOGRAPHIC FACTOR AT LATITUDE 27°37′

Low-frequency coefficient	**scale**	**DEM**	**Slope**	**Aspect**	**high-frequency coefficient**	**scale**	**DEM**	**Slope**	**Aspect**
ca1	30	-0.3568	-0.2562	0.1249	cd1	30	-0.0816	-0.1681	-0.2196
ca2	60	-0.3575	-0.2981	0.1340	cd2	60	-0.1115	0.0563	-0.3943
ca3	120	-0.3090	-0.3513	0.1442	cd3	120	-0.3624	0.0037	-0.0928
ca4	240	-0.1516	-0.3735	0.1615	cd4	240	-0.4972	-0.1945	0.0311
ca5	480	0.0778	-0.3844	0.1972	cd5	480	-0.5610	-0.2015	-0.4670
ca6	960	0.1783	-0.4200	0.1380	cd6	960	-0.0923	0.1667	0.3601
ca7	1920	0.3441	-0.3579	0.0717	cd7	1920	-0.6813	0.0008	0.4636
ca8	3840	0.3695	-0.3309	0.1204	cd8	3840	-0.3549	-0.0664	-0.1377

TABLE II. MULTI-SCALE CORRELATIONSHIP OF NDVI AND TOPOGRAPHIC FACTOR AT LONGITUDE 117°37′

Low-frequency coefficient	**scale**	**DEM**	**Slope**	**Aspect**	**high-frequency coefficient**	**scale**	**DEM**	**Slope**	**Aspect**
ca1	30	-0.3545	-0.0470	0.0355	cd1	30	-0.0673	-0.0910	0.0299
ca2	60	-0.3776	-0.0620	0.0546	cd2	60	-0.1280	0.0151	-0.2218
ca3	120	-0.4617	-0.1092	0.0947	cd3	120	0.0417	0.1106	-0.1949
ca4	240	-0.5303	-0.1319	0.1675	cd4	240	-0.2466	-0.0841	-0.1204
ca5	480	-0.7097	-0.1092	0.2870	cd5	480	0.0358	-0.1666	0.1488
ca6	960	-0.7067	-0.2837	0.4863	cd6	960	-0.7447	0.3655	-0.3845
ca7	1920	-0.7373	-0.2181	0.6156	cd7	1920	-0.7494	-0.2329	0.3446
ca8	3840	-0.8198	0.0308	0.9329	cd8	3840	-0.8132	-0.4557	0.2742

V. Discussion and Conclusion

Both the wavelet coefficient variograms of NDVI and DEM exhibit two clear scale space and the large one show large variation, which suggest that topographical factors have important roles on controlling NDVI patterns in a larger scale.

The correlationship between NDVI and slope based on wavelet coefficient show complicated variation with spatial scales which need further investigation. Some suggestions are put forward, such as using topographic unit instead of regular cells, developing other topographic factors closely related to vegetation growth.

The wavelet transform method has tight mathematics and it can gain credible results without reproduction of multiple resolution data. But the one-dimensional wavelet transform method is considerably simple and lack of statistically significant test. Two-dimensional wavelet transform method may need for better understanding of complicated landscape.

Acknowledgements

The authors gratefully acknowledge the financial support received for this work from the Science and technology department of Fujian province of China (grant no.2009Y0032 and D0710011) and also the Science and technology department of China (no. [2008] 33).

References

Brown, D.G., Cairns, D.M., Malanson, G.P., Walsh, S.J. And Butler, D.R., (1994). Remote sensing and GIS techniques for spatial and biophysical analyses of alpine treeline through process and empirical models. In W.K. Michener, J.W. Brunt and S.G. Stafford (Eds), *Environmental information management and analysis: ecosystem to global scales.* (pp. 435–481). London: Taylor and Francis.

Franklin, J. (1995). Predictive vegetation mapping: Geographic modeling of biospatial patterns in relation to environmental gradients. *Progress in Physical Geography*.19, 474-499

Nelson A, T. Oberthür, S. Cook. (2007). Multi-scale correlations between topography and vegetation in a hillside catchment of Honduras, *International Journal of Geographical Information Science*. 21(2),145-174.

Walsh, S.J., Evans, T.P., Welsh, W.F., Entwisle, B., et al. (1999). Scale-dependent relationships between population and environment in northeastern northeastern Thailand. *Photogrammetric Engineering and Remote Sensing*. 65(1), 97–105.

Walsh, S.J., Moody, A., Allen, T.R. and Brown, D.G., 1997, Scale dependence of NDVI and its relationship to mountainous terrain. In , D.A. Quattrochi and M. Goodchild (Eds), *Scale in remote sensing and GIS* (pp. 27–56). Boca Raton, FL: CRC Press.

Deng, Y., Chen F., Chuvieco E., Warner, T., and. J. P. Wilson. (2007). Multi-scale linkages between topographic attributes and vegetation indices in a mountainous landscape. *Remote Sensing of Environment*. 111(1), 122-134.