Characterization of Urban Green Pattern by Fractal Dimension Analysis

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Abstract: Land-use and land-cover changes are key causes for reducing the urban heat-island effect. Namely, they are having important inferences for many urban planning policy issues. Remote sensing techniques have been known to provide important sources for land-cover data since the past decade; as well, the green plants were regarded as the only organisms capable of converting the solar energy into the chemical energy via photosynthesis. Therefore, evaluations for type of green are still critical to examine the basic needs for urban policy making.

The degree of complexity for vegetation index values are to be characterized by fractal dimension (D); in this study. As the vegetation index values became more complex, the fractal dimension would be increased approximately up to 2. Results have shown that higher fractal dimension indicates the green cover is having a more complex shape; meaning that, the vegetation components are more diverse. A higher degree of complexity for the indices of vegetation components are reflected very well with green cover types over the urban area; thus, it can fulfill the basic need required for the urban policy making. The self-similarity of vegetation indices are able to show the degree of complexity for the green cover shape; such results would therefore be adopted to evaluate the greenness and the diversity of the city green. By assessment of the fractal dimension, it can be very useful in detecting vegetation patterns over a large urban area; not only to provide regions of diverse climate, but also the variety of ecological conditions. The output mapping can also be regarded as a variable for modeling the effects of urban development. The output mapping can also be regarded as a variable for modeling the effects of urban development.

Keywords: Fractal Dimension, Pattern Analysis, Green Cover

1. Introduction

Satellite-measured vegetation index has been utilized in various urban green cover studies, land-use and land-cover change (LUCC) is a key driver of reducing urban heat islands and has important implications for many urban planning policy issues. Remote sensing technique provides an important source of land-cover data; however, quantifying the green cover morphology over an urban area has been proven difficult, to address the information requirements of LUCC research are crucial (Read & Lam, 2002).With the availability of higher spatial and temporal resolution imagery and the development of improved image classification methods, more details of urban LUCC can be applied for dynamics of urban green cover investigation.

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Green plants are the only organisms capable of converting solar energy into chemical energy through photosynthesis (Ricotta & Avena, 1998), A Normalized Difference Vegetation Index (NDVI) is takes into account the amount of infrared reflected by plants, the NDVI is related to vegetation is that healthy vegetation reflects very well in the near-infrared part of the electromagnetic spectrum. In general, higher NDVI values typically indicate a larger fraction of vegetation.

In this study, the urban green cover were characterized by using the fractal dimension to utilize the green types of diverse over an urban area.

2. Study Area and Materials

This study examined the relation between green cover and the morphology of vegetation index in a subtropical area, the study area was performed in Kaohsiung city, Taiwan, which is the second large city, and second most populous with a population of Taiwan.

The Formosa satellite-2 with spectrum information can provide vegetation indices and growth conditions can be detected through spectrum analysis, the image was implemented for the experiment in this study, the multi-spectrum image was acquired in 2005.

3. Methodology

The topographic data can be conceptualized as representing a three-dimensional surface, where the measured value at each geographic location is represented by the height of the surface. It can be described as self-affined random fractals (Turcotte, 1997), allowing fractal dimension to be used to understand the topographic roughness.

3.1. Fractal dimension

In general, the greater the fractal dimension of the surface, the rougher the surface is (Glenn et al., 2006). Hence, Surface patterns can be represented by quantitative measurements that vary continuously across the landscape, the shapes are frequently characterized via the fractal dimension of the object (Krummel et al., 1987; Ripple et al., 1991), and it can be applied to spatial features over a wide variety of scales.

The degree of complexity of a polygon is characterized by the fractal dimension (D), for simple Euclidean shapes, D = 1 (the dimension of a line). As the polygons become more complex, the fractal dimension increasingly to 2. Papanicolaou et al. (2012) has demonstrated four different outlines (perimeters) with increasing degree of convolution, Figure 1 (D) illustrates object outlines with greater degree of convolution than the object of Figure 1 (A).

3.2. Fractal Analysis

Green cover have been recognized to be fractal structures, presenting self-similar properties over a significant range of scales. The impact of these results is significant in studies on urban area and on determination the diversity of green cover.

The method is based on to equals 2 times the logarithm of patch perimeter (m) on NDVI which divided by the logarithm of patch area (m2) and the perimeter is adjusted to correct for the raster bias in perimeter, when fractal dimension greater than 1 for a 2-dimensional pattern, that indicated the shape show an increase trend in shape complexity, the fractal dimension could reflects shape complexity across a range of spatial scales, because the landscapes in this technique are grid based, consisting of square cells, and having a square shape, hence, to calculate the constant of proportionality between area and perimeter for a single cell, the formula is based on calculated slopes as follows:

$$P = 4 * A^{D/2} \tag{1}$$

and

$$D = \frac{2\ln(.25P)}{\ln A} \quad ;1 \leqq D \leqq 2 \tag{2}$$

where

A = total patch area and
P = total patch perimeter.

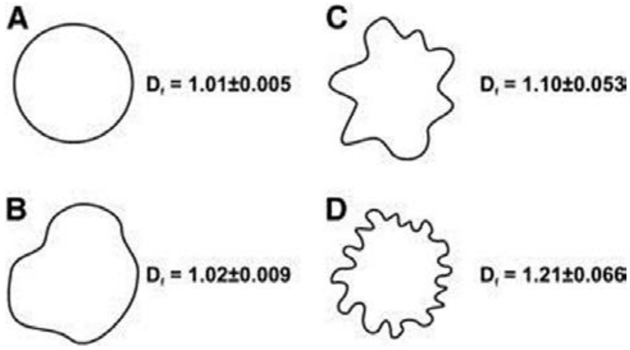

Figure 1. The degree of complexity of a polygon is characterized by Fractal Dimension (FD). (Modified from Papanicolaou, Tsakiris et al. (2012)).

3.3. Normalized Difference Vegetation Index (NDVI)

To determine the density of vegetation on a patch of land, distinct colors (wavelengths) of visible and near-infrared sunlight reflected by plants must be examined. Nearly all satellite vegetation indices employ the following difference-formula to quantify the density of plant growth on the ground: near-infrared radiation minus visible radiation divided by near-infrared radiation plus visible radiation. The result of this formula is called the NDVI (Normalized Difference Vegetation Index).

4. Results and Discussion

Fractal is a shape of object is independent of the scale at which it is observed, also referred as `self-similarity'(Turcotte, 1997). Fractals offer significant potential for quantitative analysis of the spatial complexity of remotely sensed image(Ricotta & Avena, 1998). The NDVI estimated the amount of infrared reflected by plants, the self-similarity properties can be discovered by employing fractal analysis, the similarity of NDVI value also reflected the complex of a surface, the results shown as follows.

The results of fractal dimension shown as Figure 2, high fractal dimension indicated that the green cover has a complex shape, meaning that the vegetation component is more diverse, as the purple and red symbol in Figure 2, a high complexity of the vegetation component reflects very well of green cover types over the urban area, which can fill up the basic required of the urban policy. The self-similarity of vegetation index shown the complexity of the green cover shape, the results can be used to evaluate the greenness and the diversity of green city.

To assess fractal dimension may be useful for detecting vegetation patterns over large urban areas and providing regions of diverse climatic and ecological conditions. The output map can be also regarded as a variable for modeling the effects of urban.

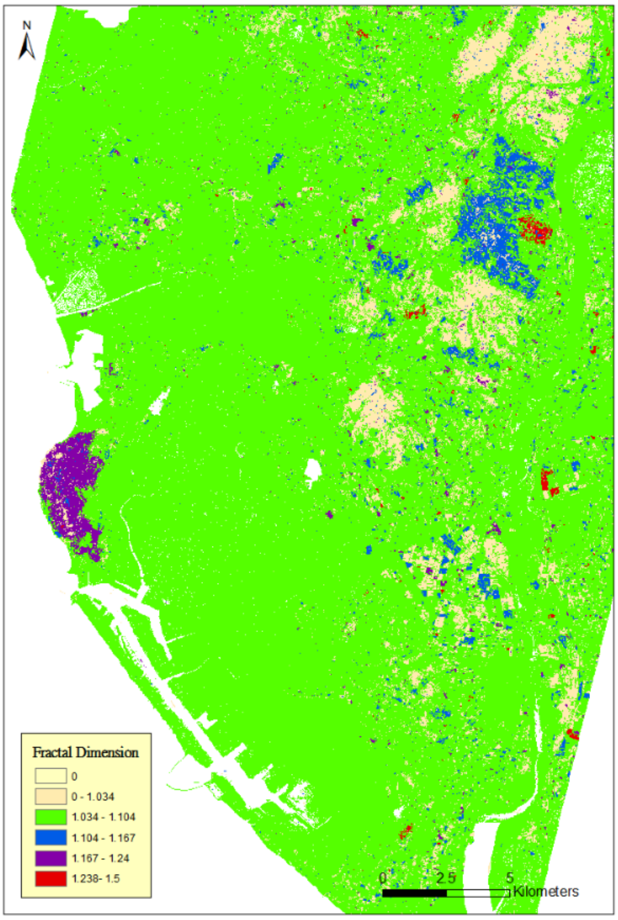

Figure 2. The vegetation component of Kaohsiung city.

References

Glenn, N. F., Streutker, D. R., Chadwick, D. J., Thackray, G. D., & Dorsch, S. J. (2006). Analysis of LiDAR-derived topographic information for characterizing and differentiating landslide morphology and activity. *Geomorphology*, **73**(1-2), 131-148. doi:10.1016/j.geomorph.2005.07.006

Krummel, J., Gardner, R., Sugihara, G., O'neill, R., & Coleman, P. (1987). *Landscape patterns in a disturbed environment*. Oikos, 321-324.

Papanicolaou, A. T., Tsakiris, A. G., & Strom, K. B. (2012). The use of fractals to quantify the morphology of cluster microforms. *Geomorphology*, **139**, 91-108.

Read, J., & Lam, N. S.-N. (2002). Spatial methods for characterising land cover and detecting land-cover changes for the tropics. *International Journal of Remote Sensing*, **23**(12), 2457-2474.

Ricotta, C., & Avena, G. C. (1998). Fractal modelling of the remotely sensed two-dimensional net primary production pattern with annual cumulative AVHRR NDVI data. *International Journal of Remote Sensing*, **19**(12), 2413-2418. doi:10.1080/014311698214802

Ripple, W. J., Bradshaw, G., & Spies, T. A. (1991). *Measuring forest landscape patterns in the Cascade Range of Oregon*, USA. Biological Conservation, 57(1), 73-88.

Turcotte, D. L. (1997). *Fractals and chaos in geology and geophysics*: Cambridge university press.