FRACTAL DIMENSION OF URBAN EXPANSION BASED ON REMOTE SENSING IMAGES

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Abstract: Fractal Dimension of Urban Expansion Based on Remote Sensing Images: *In Cluj-Napoca city the process of urbanization has been accelerated during the years and implication of local authorities reflects a relevant planning policy. A good urban planning framework should take into account the society demands and also it should satisfy the natural conditions of local environment. The expansion of antropic areas it can be approached by implication of 5D variables (time as a sequence of stages, space: with x, y, z and magnitude of phenomena) into the process, which will allow us to analyse and extract the roughness of city shape. Thus, to improve the decision factor we take a different approach in this paper, looking at geometry and scale composition. Using the remote sensing (RS) and GIS techniques we manage to extract a sequence of built-up areas (from 1980 to 2012) and used the result as an input for modelling the spatial-temporal changes of urban expansion and fractal theory to analysed the geometric features. Taking the time as a parameter we can observe behaviour and changes in urban landscape, this condition have been known as self-organized – a condition which in first stage the system was without any turbulence (before the antropic factor) and during the time tend to approach chaotic behaviour (entropy state) without causing an disequilibrium in the main system.*

Key-words: fractal dimension, urban growth, image processing, urban growth,

1 Introduction

The history of urban expansion indicates that the urban areas are one of the most dynamic places on the Earth's surface. The process in change in land use is the result of urbanization and at the same time it is cause of urban environmental problems, reflecting the direct and indirect relations between natural environment and human activities. Study the land use change and the implication of anthropic actions is essential not only for detecting the global environmental change but also for framing suitable strategy for land planning on a local scale. Urban sprawl is commonly used to describe physical expanding of urban areas and used as an indicator of industrialization and usually has a negative impact on the environmental health of a region (Peng, Xu, Xue, & Yang, 2012).

In the specialized literature, the expression *urban sprawl* refers to the pavilion type of residential developments, outside the cities together with other activities that lead to important environment, functional and landscape changes (Bogdan, et al., 2010).

A city can be approached as a system which contains components of complexity and nonlinear spatial pattern which has inherent characteristics of self-similarity and self-composition. In order to analyse the roughness of city shape is important to look at its structure (Frankhaouser, 1990).

The Cluj-Napoca city during the time has been implying a fast development of urban areas and tends accelerates the conversions from agriculture land to construction land, and has an extremely impact on the society and environment.

Using images provided by remote sensing satellite, implication of GIS techniques and fractal theory gives us a unique perspective of how Cluj-Napoca city extend, and the

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possibility to use them as a monitoring method for a better land planning.

2. Study are and data used

This study is concentrated on Cluj-Napoca city (Fig. 1), located at $23^{0}36$'E and $46^{0}46$'N with a total are of 88, 2 km^2. We have applied multi-temporal and multi-source remote sensing (RS) data to monitoring the environment of Cluj-Napoca city using fractal theory and GIS techniques.

In this study we used different types of data like: topographic map (scale 1:5000), land use map (CLC – Corine Land Cover), orthophoto and multi-temporal RS images of Landsat 5 TM (Thematic Mapper) and SPOT 5 (Tab. 1).

Image	*Data*	*Spatial resolution (m)*	*Number of bands*	*Radiometric resolution*
SPOT 5	16.08.2007	1 x 1	5	8 bit
LANDSAT 5 TM	2000	30 x 30	7	8 bit

Table 1 – Satellite images

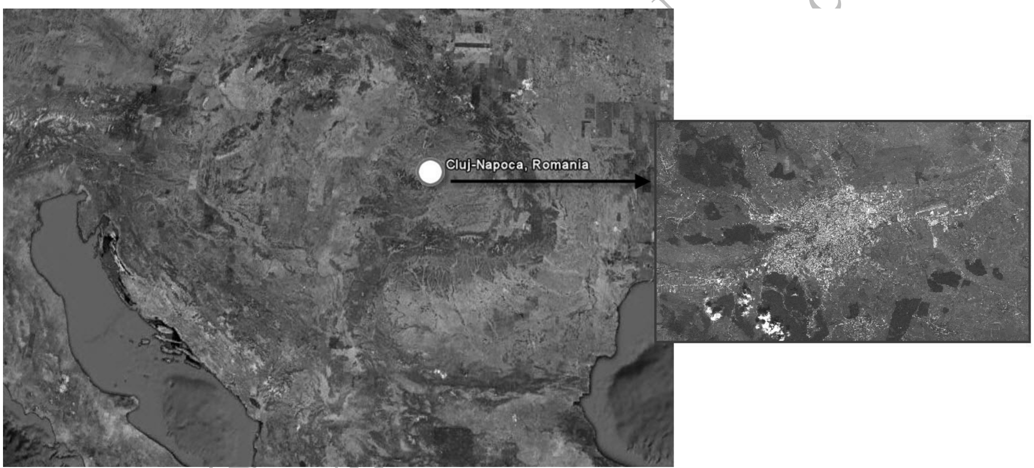

Figure 1 – Location of the study area

2. Methodology

Image processing involves a chain of procedures that includes co-registration, classification (supervised in our case), geometric transformation and correction (Fig. 3) of the data and digital enhancement, which implies a better interpretation. Applying different filters for digital enhancement don't affect the image matrices or the output result. Thus, for these process it was used the Envi 4.7 and ArcGIS 10 software which have allowed to analysis and extract the information we need.

a) *Image processing and data analysis*

The RS data present in this study implies a number of errors which appears because the satellite sensors have been record the data close to the true value. In the first phase we applied a co-registration process to solve the geometric problems and assure each pixel in all the satellite image corresponds to each other. Geometric correction was applied to SPOT images using 1:5000 scale topographic maps. The result was a rectified image which served as the source to rectify the Landsat images by the use of image-to-image registration method and was resampled using a cubic convolution algorithm (Jiazheng & Stephen, 2008). For the registration process *The Root Squared Error* (RMSE) was 0.21 pixels, after verification calculation.

b) *Classification based on Supervised Methods*

In this stage was chosen for the classification the Maximum Likelihood (ML) method which assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. The ML was processed in Envi 4.7 software. Because the ML is a supervised classification method, it was necessary to include a set of training samples (TS). The TS were digitized on-screed based (Fig. 2) on terrain knowledge acquired during fieldwork and scattered all over the study areas. Each class which represented the TS was checked so all classes could be separated in at least one combination of bands.

The analyst search and identifies in the satellite imagery uniform representative samples of the different surface cover types of interest based in a supervised classification (Peng, Xu, Xue, & Yang, 2012). This is based on the statistics of training areas representing different ground objects selected subjectively by the analyst on their own knowledge. The computer used the numerical information (spectral respond) to recognize spectral similar areas for each class based on the numerical information from all of the spectral bands. After the computer has determined the signature for each class, each pixel in all of the images is compared to these signatures and labelled as the class it most closely look like in numerical form. The data will be extracted from the satellite images and combined the clustered output to produce a map of change, in the interest region. Once we have the results in a cluster form, a segmentation algorithm will be applied that exploits the direct correlation between neighbouring pixels and then extract the features into polygon forms.

Figure 2 - Training samples

c) Fractal dimension and computation process

A city can be identified as a fractal by using a scale *r* which measure the lands use and a measurement function M(r). Thus, when *r* changes M(*r*) will change accordingly (TaoGang & Chi, 2009). The relationship between them is illustrated below:

$$\mathbf{M\ (r)} \propto^{\pm\delta} \quad (1)$$

Where δ is the fractal dimension scale and represents the depth of all the images. Fractal dimension can be calculated by using different methods like: box-counting method, turning radius, geometry measure relationship, fractal Brownian motion. In this paper we approached the box-counting method which takes as input the following parameters: an object F which is the city on the 2D plane, then F is covered by a grid with the length δ. The number of squares which intersects the F is N. N is used as a power by $N(\delta) \propto \delta^{-D}$, then $\delta \to 0$ and the logarithmic relation is $D = \frac{\ln N(\delta)}{\ln(\frac{1}{\delta})} D$ (Ye & B., 2001).

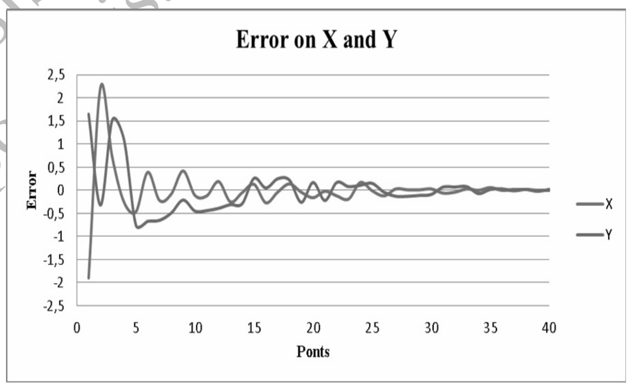

Figure 3 - Points error

3. Analysis and Results

Using the fractal theory, RS and GIS techniques we were able to extract the urban expansion information form satellite images. The data of urban land cover change provides multi-temporal information in the form of urban growth mapping. The urban expansion inside the study area in 2000 and 2007 are presented in Figure 3. Urban change during the time is represented in Figure 4. The colours applied for classified images represent urban land cover for two different years. The blue colour delineates those areas of urban cover in 2000, and the red for urban areas in 2007. This shows the changes in expansion of existing urban areas are complex and indicate a higher fractal dimension

(1, 89). These complex structures denote a deep fragmentation degree and a week stability of urban structure, which appear to be more damaged than before. Relation between every cell and the object (city shape – edges) is illustrated in Figure 4.

The urban expansion of Cluj-Napoca city from year 2000 to 2007 is about 7%. Tendency is to expend more and include the existing metropolitan are into future city. In the image presented, blue areas show the extent of the urban area in 2000 (Figure 3 - b), while the red areas show what was built up in the 7 years afterthat (Figure 3 – d). In this case the road infrastructure presents an important role for

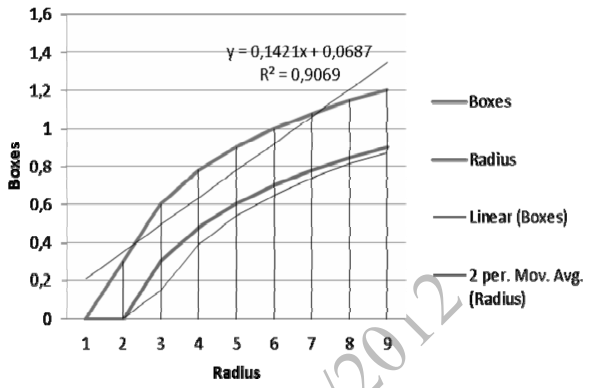

Figure 4 - Fractal dimension

urban expansion and looks that the city extend tentacular.

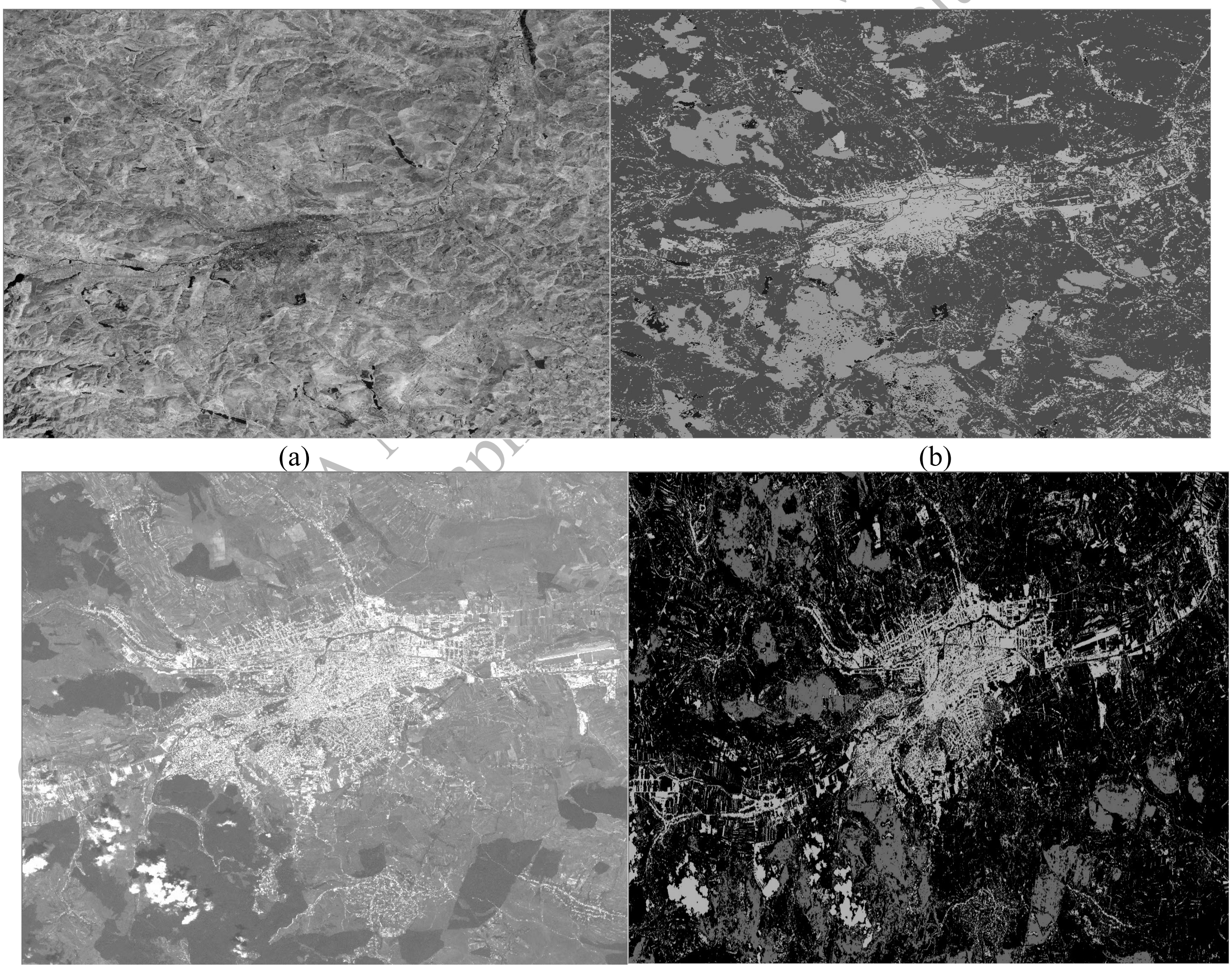

Figure 3 (a) Landsat band combination; (b) ML classification map for May 15, 2000 (4 classes); (c) panchromatic SPOT image for October 11, 2007; (d) Panchromatic image classification (4 classes).

If we analyse and compare the information (images) from 2000 to 2007 we can see the spatial patterns of urban sprawl in Cluj-Napoca city becoming clear. Urban areas expansions has occurred along road infrastructure and tend to connect the cluster built up areas of country side.

This trend in spatial development of Cluj-Napoca city implies that the town hall must provide adequate housing, schools, health care services, water to dispersed people and reduce the problems which can appear into isolated communities.

Thus, the urban expansion is a complex process which involves two factors human and nature. The tendency of those factors can be predictably in space and time if the area is monitored during the time. In this way the city planning will be more effective.

4. Conclusion

Based on the fractal theory, in order to analyse the urban structure of Cluj-Napoca city and using the remote sensing data, we managed to identify different fractal forms. Expansion of urban site has been accelerated from 2000 to 2012 which was reflected by the increase of fractal dimension of images. Rapid conversion of the natural land into built-up areas is heterogeneous. Land being inadequate used by the government may need to develop different policies to maintain the intensive cropping and encourage peri-urban agriculture (Barredo, Kasanko, McCormick, & Lavaller, 2003). A lack of any land use planning may lead to land degradation. The accessibility of RS data and fractal theory has been helpful for mapping spatial features, providing dependable, suitable, and precise data.

Fractal dimension method can be applied over a large area, and using the GIS techniques to provide different tools to analyse and create planning scenario, for government decision. Thus, fractals are an important tool to monitor dynamic change of urban expansion form the earth observation data.

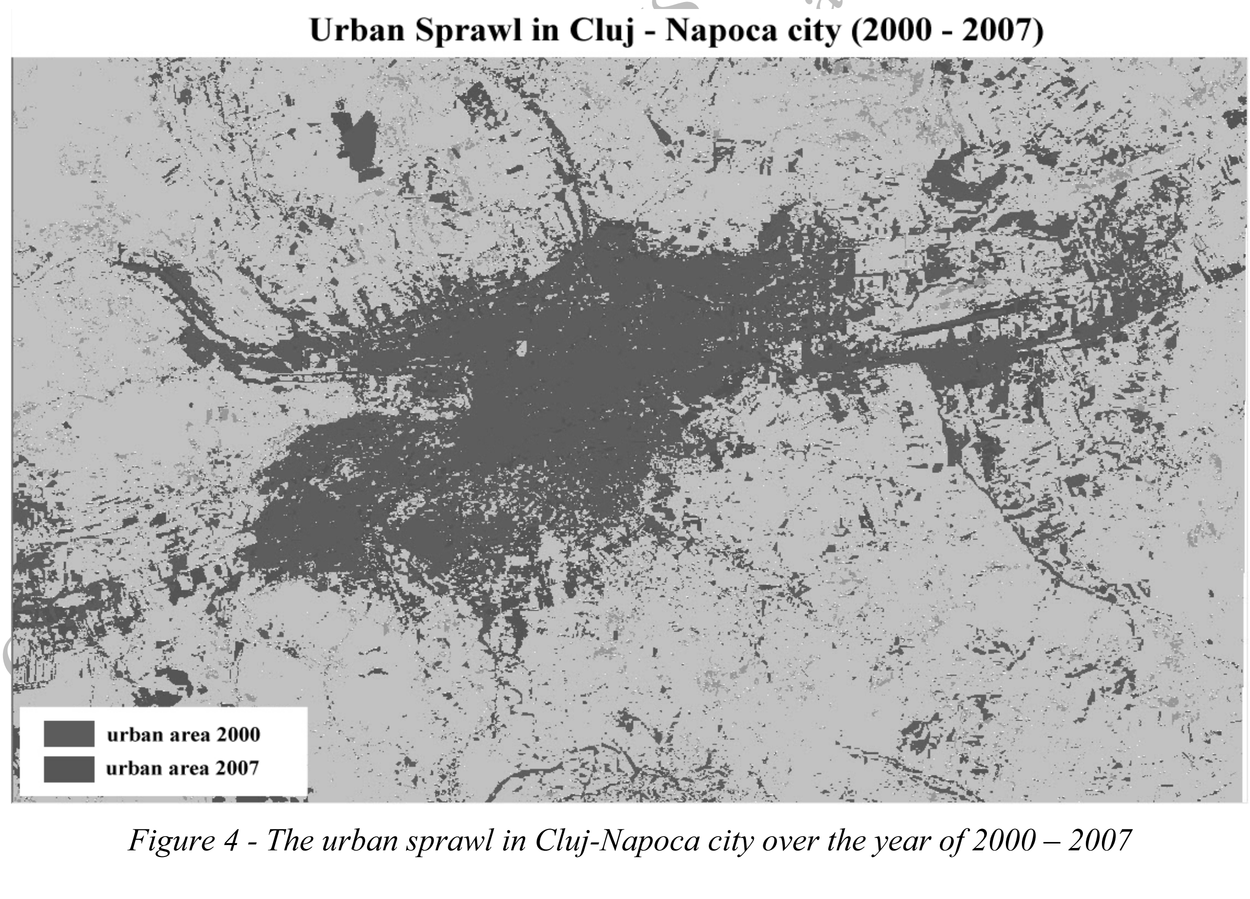

Figure 4 - The urban sprawl in Cluj-Napoca city over the year of 2000 – 2007

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