APPLICATIONS OF FRACTAL GEOMETRY IN MORPHO-HYDROGRAPHIC NETWORK OF THE DANUBE DELTA POTAMOLOGY

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***Abstract**: Fractal geometry is a tool in the analysis and interpretation in Potamology. Delta, is a typical case of alluvial river that occurs at the mouth of the great rivers loaded with a large amount of silt and opens into smooth waters, usually saline (seas and oceans) which has shallow waters and a shelf extended where tides (in most of the cases) are of low intensity and where currents coastline, with different meanings are weak, allowing the appearance, submersible or on surface of bars or a flat surface cone of dejection on which the river it spreads its waters in a web of streams, canals and lakes.*

A fractal is a geometric entity which, in its spatial development, is multiplying more and more on a smaller scale. An essential characteristic of fractals is that if you look with a magnifying glass, any part thereof, is reproducing at a smaller scale, the figure of the whole fractal. Fractal Analysis of the mouths of the Danube show a particular hydromorphological dynamics with specific mechanisms important for the exchange of energy and matter.

The high degree of complexity of the Danube course determines the occurrence of several degrees of freedom in the course of the bed, reflected in an intense development and decreased predictability.

On the other hand, the fractal dimension analysis of morphologically homogeneous sections of the course, emphasizes the geometric homogeneity of the lower Danube by similar values thereof.

As engineers and scientists, we have become aware that water management involves a holistic and integrated view of a number of distinct systems that would previously have been dealt separately, and consequently there is a need for collaboration with experts from a number of other disciplines. Also we have to take into account the requirement of a range of stakeholders who have a direct interest in Danube Delta ecosystems functions. We have to note the Danube Delta water circulation (DDWCS) system deal with very complex interactions that are not immediately apparent. Simulation modeling has therefore become an important tool in order to understand the behavior under changes to various boundary conditions or internal conditions, such as parameters or even functional representations of different identified phenomena.

***Keywords:** Danube Delta, morfohidrographic network, fractals*

1. Introduction

A fractal can be simply understood as a model where there are smaller models but similar, for example, the geographical characteristics of morphohydrographic networks, and maps at scales much larger than models of maps at small scales for the same geographic region. This article tries to argue and provide evidence for the applicability of fractal theory in the study of the Delta morphohydrographic network.

Fractal structure is a basic feature of the geographical phenomena, whether natural or manmade, that make reality might be mapped by large-scale map through the process of generalization - otherwise fractal nature underlying mapping process by introducing key concepts, like fractal recursion and self-similarity, ratio scaling and the exponent scaling.

Almost all chaotic systems can be quantified by the fractal dimension. Fractal dimension is a fraction, which describes how an object occupies a space. Objects in space (and the systems that create them) are infinitely complex. Depending on the scale at which the object is examined there will be different levels of detail. In addition to the levels of detail, most objects in nature have the property of self-similarity, fundamental characteristic of fractals. For this reason, fractals maintain their size, with regard to the used scale. This is evident for natural elements such as: mountains, coastlines, clouds, hurricanes and lightning.

Fractal Dimension Index (FDI) is a tool that applies the principles of chaos theory and fractals. This indicator identifies a method to measure irregular natural objects called fractal dimension calculus. The FDI is based on formulas determined by Mandelbrot and Hurst.

Mandelbrot was the first to apply fractal theory on the different systems in nature. It has also shown that disruption of the dimensional consistency empirical dependence of the length of the river of the surface of the watershed may result from the nature of the river 2D fractal model (Mandelbrot, 1982). This observation underlies this work.

With their appearance, fractals have found wide application areas. They are now found in mathematics, medicine or even cinema. One of the first areas that adopted the fractal theory is geography. (Kalanyos, 2002)

"Fractals" were introduced by Benoit Mandelbrot in his book "Les objets fractals, shapes, Hasard et dimension" (Mandelbrot, 1984). The term comes from the Latin "fractus" - France, fringe (which in turn comes from the verb "break" - to break, to break) and suggests two main differences of fractals to the "classical" mathematical objects, ie: they are smooth but have completely irregular border; not a single piece but are composed of an infinite number of parts, all reduced-scale copies of the whole. (Nikora, 1991)

After the appearance of his article "Fractal objects" Mandelbrot has exhibited extensively his theory in 1982 when he published the book "The Fractal Geometry of Nature". In an attempt to detail the term "fractal" and regular occurrence of the phenomenon in nature, Mandelbrot gave the explaination by the following definition: "a geometrical figure fragmented or broken can be divided into parts so that each of them is (at least approximately) a miniature copy of the whole". (Mandelbrot, 1982)

Alternatively, the idea of Mandelbrot fractal theory began to investigate the structure addressing rivers systems (Tarboton, et al, 1988, La Barbera et al, 1989 or Nikora, 1991). This led to a new feature of the river basin network: the fractal dimension. In general fractal nature manifests itself in two ways:

- character "disheveled" - typical for most drainage networks composed of different degrees tributaries and main course, but also the networks 'distribution' in difluents of varying degrees, as in the case of the Danube Delta,

- 2D model of individual courses in networks.

There were many different notions dimensions for general sets, some much easier to be calculated and more convenient in applications. This paper focuses only on Hausdorff dimension. Hausdorff introduced the definition of its dimension in 1919, and this was used to study the famous objects such as the Koch snowflake curve. In fact, its definition was based on previous ideas of Carath'eodory. Moreover, it made contributions and applications, particularly in number theory, made by Besicovitch.

It could be given a mathematical provisional definition of a fractal for the Hausdorff dimension as a set strictly exceeds the topological dimension once those terms are defined. However, this is not entirely satisfactory because the rule does not take into account fractals fractals. This use of fractals is mainly due to Benoit Mandelbrot. (*Lectures on fractals and dimension theory).

The basic idea behind Hausdorff dimension is to generalize the process of measuring a set by approximating (covering) it with sets whose measure is already known. Especially, the size of the sets used in the measurement process will be manipulated by certain trans-formations, thus making it harder or easier to approximate a set with a covering of small accumulated measure. (** Effective Hausdorff dimension)

This paper aims to identify the geometrical parameters which reflect the internal structure of morphological sections of Sf. Gheorghe Branch of the Danube River, by using the concept of fractals.

2. Material and Methods

To calculate the fractal dimension of the study areas, it was used BENOIT ™ application - TruSoft Inc. BENOIT ™ is a fractal analysis software for Windows that allows calculating fractal dimension and / or Hurst exponent datasets using the choice of method for analyzing similar car models and traces autoafine. A white noise filter (Fourier or Wavelet) and trace generator autoafine are two additional features of the program. BENOIT ™ is an important resource for the study of fractal models and methods and analysis tool for researchers and students analyze data in economics, earth sciences, physics, chemistry, biology and other disciplines. (*** TruSoft Inc., 2012)

It can be choosen one of the following methods of analysis:

- computing, boxing, information, perimeter, area, and similar self-table model analysis (2D data);

- R / S, power spectral analysis, variogram, roughness length and wavelets analysis of trace autoafine (1D data);

- Data fragmentation size - frequency (1D data).

Filtration is in the program to enable white noise removal from the introduced scheme techniques, using Fourier or Wavelet. The program can also generate traces of synthetic autoafine using a local generator parameters that can be established from the start.

BENOIT ™ program window is a tool for research and study for anyone interested in fractal properties and data sets. The program automatically calculates the default values for a range of parameters adjustment or performance can control for each parameter. The interactive data packages allow disabling points outside the range of fractal to increase accuracy. (*** TruSoft Inc., 2012)

The goal of the fractal analysis is to interpret the geomorphological characteristics and to better understand the processes of geomorphological evolution of Sf. Gheorghe branch; to identify and describe geomorphological phenomena responsible for any difference or convergence through a fractal dimension; and to classify hydrographical patterns.

According to the geological and geomorphological characteristics, the Delta indices, the low fractal indices reveal a prevailing tectonic, active or not, while high values of the indices indicates deposition processes / warping / erosion stronger on the inherited landscapes.

Genesis of Sf. Gheorghe arm is a gradual and complex phenomenon and depends on various factors and processes that interact during the long and short time periods: structuring tectonic basin and lithostratigraphic features, data bank erosion and development of channels and islands, soil and climate factors.

From this study results Sf. Gheorghe is possible to obtain from the fractal dimension, the primary and secondary processes behind modeling, distinguishing dynamic morphological events responsible both for the arms' morphology and for the identification of the predominant phenomenon. In fact, the fractal dimension D = 1, characterizing the Euclidean dimension of a line, can be compared with the theoretical value obtained for a high geometric regularity (in this case a large number of hydraulic interventions for regulating the meanders). In nature, in the specific case of a hydrographic network where the D~1 (low value) can be value-oriented forms of a monodirectional genesis. Instead, a fractal dimension greater than 1 shows the characteristics of a heavy curved segment (meandered course). In this case, the fractal dimension is given the large number of meander and islands (erosion and deposition), characterized by solid and liquid flow variations.

In short, on this basis, the whole of the value of fractal dimension indicates the primary processes (eg direct form due to tectonic or older), while the decimal part indicates the secondary (eg irregular shape due to clogging or erosion).

Fractal analysis is a valuable tool that can examine and describe the course of the Sf. Gheorghe arm. The application of fractal geometry provides a methodological and quantitative contribution to detail the analysis of the relationship between the geomorphological processes and the degree of convolution of the arm, in order to develop the scenarios of its development.

In order to determine the fractal dimension corresponding to study area, we analysed the evolution of Sf Gheorghe branch, using the first existing map- Hartley's map (Figure 1).

Figure 1. Danube Delta Map 1870 – Hartley: Ismail and Sf. Gheorghe splits

(European Comission of the Danube, 1870-1871)

Based on this map, we digitized the naturally Danube, before the hydraulic interventions. For this, we used ArcGIS software (for georeferencing the map and bringing it to scale) and Corel Draw (to digitize the watercourse on the analyzed sector).

In the process of digitalisation of the map, was obtained a file type *.cdr containing the digitized banks of Sf. Gheorghe branch.

Subsequently, this file has been converted to image format, *.bmp black and white. The scheme thus obtained was introduced in the application software Benoit- True Inc. for the automated calculation of the fractal dimension (Figure 2).

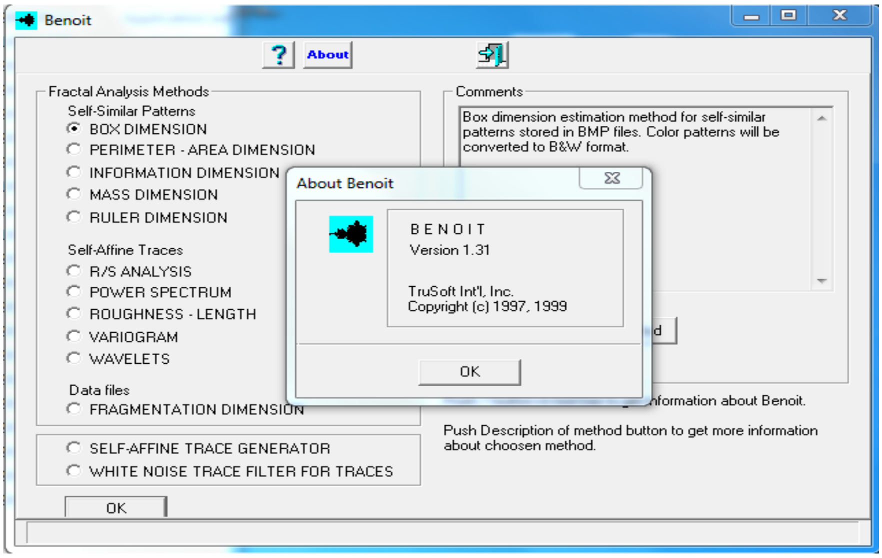

Figure 2. Benoit Software first page

3. Results and Disscussions

Running the previously presented software has led to the result that can be studied on figure 3.

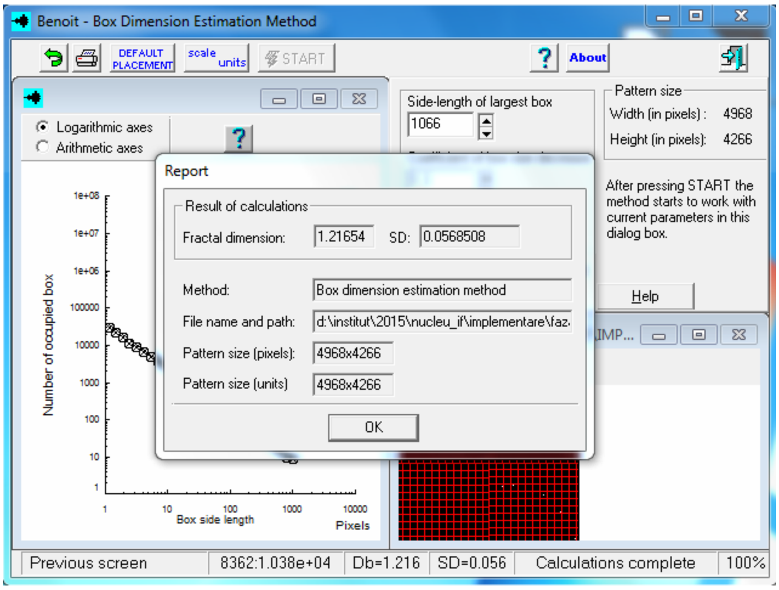

Figure 3. Results of calculation

By running the application for the 1870 Harley Map, we obtained a D- fractal dimension for Sf. Gheorghe equal to 1.2165. It may be noted that this value is close to the ideal value of the rivers in their natural state, 1.2. However, due to the value greater than 1, it is noted the meandered character and deposition of sediments in the arm.

Was applied the same method for calculating the fractal dimension of the current form of Sf. Gheorghe. As the current geographical information, we introduced the digital cartographic high resolution ortophotoplans collected in 2011, with accurency of 25 cm. After georeferencing and digitizing the orthophotoplans and after converting the files to the required form of application Benoit, we obtained an outline of the homogeneous segments analyzed. It followed the introduction of the scheme obtained (Figure 4) in the BENOIT program, with the following results:

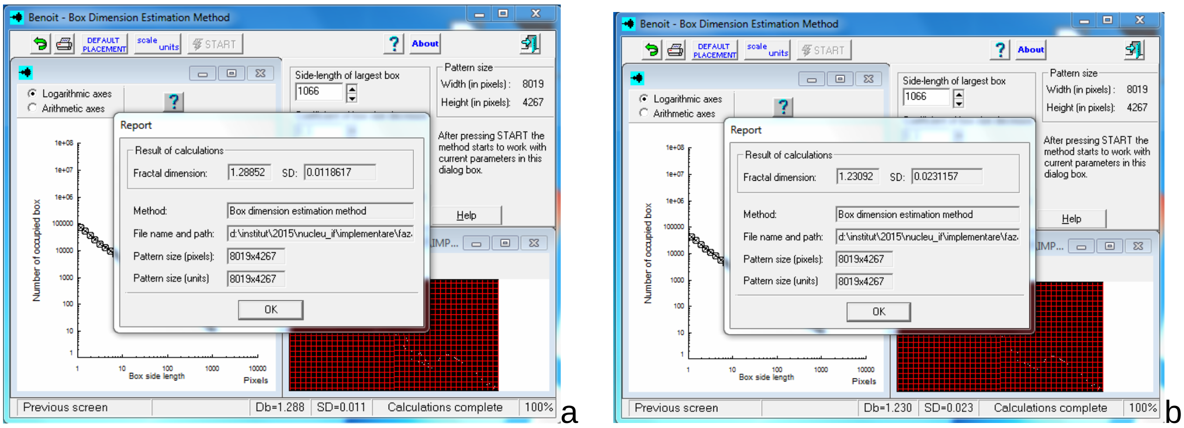

Figure 4. Introducing the shape of Sf. Gheorghe arm and the final result of the fractal dimension (a- on the actual state; b- on the future scenario, with islets)

After running the application for the second situation-the orthophotomap 2011, it was obtained the fractal dimention of a omogen segment. Sf. Gheorghe's arm is equal to 1,289. It can be seen that this value has increased thanks to the new structures appearing hydro geomorgologice (islands and canals), increasing the convolution property arm.

Thus, after processing the data available: the map of Sf. Gheorghe’s arm in the 1870 and 2011 orthophotomap, finds that, following the work of embankment, the fractal dimension increased from 1.21 to 1.29.

It followed the evolution of the script development arm reviewing the data collected on the dynamics of this area. The proposed scenario provides the extinction meanders and sanitation interventions on areas with hydraulic flow, with the development and emergence of islands on the course arm (in the situation is not interfering in any way). In this case, the fractal dimension has a value of 1.23, indicating a tendency to return the arm to the natural state (D = 1.2).

Fractal dimension of the three stage time is within the range of 1- 1.5. This suggests that the morphology of the Sf. Gheorghe arm is the result of recent geomorphological processes (deposition of sediments) over an inherited form and structural control.

Finally, our results suggest growth assumption fractal dimension in correspondence with a gradual transition from a network meandering towards a network channeled right, but other forms encountered due to interventions hydro, corresponding to progressively greater influence processes erosion and morfoselection, which will lead in time (and without hydraulic interventions such as dredging, channel cuts or other) to return meandering shape of the arm. Thus, networks meandering developed by overlapping patterns of current deposit on a landscape inherited but is molded due to hydraulic interventions in the hydrological regime different from the previous situation, but with a tendency to return to its natural state.

4. Conclussions

Using the method of the fractal analysis, it can be analyzed the hydromorphological dynamics of the Danube Delta. The fractal dimension can reveal the influence of the hydrotechnical works and other actions concerning the spatial planning of a river, but also the rivers’ property of self-similarity.

The high degree of complexity of the Danube Delta determines the occurrence of several degrees of freedom in the course of the bed and is reflected in an intense development and decreased predictability.

The hypothesis of return of Sf. Gheorghe arm- the case study chosed for this analysis, at the natural state is also confirmed by analysis of fractal dimension, by comparing the three temporal stages (map analysis on Hartley's 1870 map, the 2011 orthophotomap and the short term future scenario). The value of this indicator oscillates on the 3 stages of analysis from 1.21 to 1.29 and 1.23.

Fractal dimension of the three stage time is within the range of 1- 1.5. This suggests that the morphology of the Sf. Gheorghe arm is the result of recent geomorphological processes (deposition of sediments) over an inherited form and structural control.

Finally, our results suggest the growth assumption of the fractal dimension in correspondence with a gradual transition from a meandering network to a right channeled network, but other forms encountered due to hydrotechnical interventions, corresponding to progressively greater influence of the erosion processes and morfoselection, which will lead in time (and without hydraulic interventions such as dredging, channel cuts or other) to the return to the meandering shape of the arm. Thus, the meandering networks developed by overlapping patterns of current deposit on an inherited landscape but molded due to hydraulic interventions in the hydrological regime different from the previous situation, with a tendency to return to its natural state.

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