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The Use of Morphological Theories in Geographic Researches

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Abstract:

Morphological theories have an innovative role in the geographic researches, firstly through its objective study-the world of forms-and then through its structural, qualitative and non – reductionist method. In the geographic research, a great impact is held by the fractal analysis because almost all entirely geographic forms are fragmented, uneven, discontinuous, not being able to fit to Euclid geometry.

Key words: morphological theories, catastrophe theory, dissipative structures theory, determined chaos theory, fractal theory, fractal dimension, critical value, river basin

1. Theoretical Aspects

The morphological theories try to describe and explain the appearance, maintenance and disappearance of forms, try the understanding of genesis and their stability.

According to Rene THOM, the purpose of morphological theories is that to specify those spatio-temporal configurations which they can form in a stable and repetitive way.

The morphological theories allow to approach mathematically the forms' world, exceeding the bias that the science should be quantitative.

The forms present themselves as a resultant of elementary physical changes and it is only one from the numerous reactions of the sphere. The forms are a fundamental qualitative notion. These cannot be a measure as mass, speed, temperature and they do not know the principle of conservation.

We observe that the universe of morphological theories is not one of precision, but the uncertain world of daily existence.

A. The Catastrophe Theory

The Catastrophe Theory was issued by Rene Thom. According to him, the "show" of Universe is an uninterrupted moving of birth, development and destruction of forms.

The term of catastrophe is not related to a tragic, unexpected event, which disturbs dramatically the natural order of things or world, but a catastrophe producing when continuous variation of causes determines discontinuous variations on effects. The catastrophe contradicts "causa aequat effectum" and "effectus non est potior sua causa" principles.

According to Rene Thom the catastrophe is associated to any phenomenological discontinuities. Thus, when a function has a discontinuity in one point, that point will be considered catastrophic.

According to the catastrophic theory, everything that surrounds us are forms, structures equipped with stability, occupying a certain position in space and as duration - a certain period.

In order for a form to exist, there should appear a discontinuity in the qualitative properties of support. If the background is perfectly homogeneous, the morphology cannot exist. Thus, the opposition continuum/discontinuum stays at the base of our perception of the world and its things.

B. The Dissipative Structures Theory

The Dissipative Structures Theory was issued by Ilya Prigogine. This theory does not approach the form with the cooperative processes. This term designates the self-defence phenomena (Dissipative Structures) which can appear in certain cases and conditions, in population made from identical individuals.

The Dissipative Structures check the appearance, apparently spontaneous, of an order, namely a spatial or temporal morphology in the interior of a system made from a number of entities and subjects to special and external constraints.

In contradistinction to equilibrium structures, which once created need not by energy intake in order to be maintained, the Dissipative Structures are formed and stabilized by matter and energy flow, which change with the environment.

C. The Deterministic Chaos

The deterministic chaos theory appeared and developed in USA and Europe at the end of the ‘60. The name was given by the mathematician James York, who worked on the term of chaos having a precise statute and meaning. The theory of deterministic chaos is trying to find a way of understanding phenomena categories apparently disordered and chaotic, unexplained in other ways. The chaotic system is a deterministic system with a stochastic behaviour, being apparently random.

On the big systems the changes are made at the marginal zone and on the small systems, they are made integrally.

The particularities of a chaotic system are:

- the contradiction of premises of sense;
- the catastrophes are because of external causes, the small detail being important in their understanding.

These can decide their extinction or accelerating (triggering of an avalanche);
- the scale of negligible factors (the other's pit notion, moon remoteness);
- the internal time of system checks not with the time of observer.

D. The Fractal Theory

The fractal theory was issued by Benoit Mandelbrot and deals with a certain family of fragmented, irregular, fractioned, discontinued forms.

The fractal is a geometric structure or a natural object which combines the following features:

- The parts have the same form or structure as the whole; even in the case when these have different scales, they can also be slightly deformed;
- Its form is extremely fragmented, irregular, interrupted, whatever is the scale thereupon is made the examination, not being able to describe thus by the language of Euclid geometry, both locally and also globally;
- It is generally self-similar, eventually, statistically self-similar;
- It is defined in most of cases by very simple laws, possibly recursive;
- It has sometimes a superior fractal dimension to that of a topological dimension.

The fractal dimension is a number that counts the irregularity and fragmentation degree of a geometric structure or of an object from nature, a number which, in the case of Euclid geometry objects, reduces even at their ordinary dimension. [10]

There are more ways for measuring these irregularities, the most often used being:

- The Hausdorff-Bezicovici dimension;

- The Minkovski-Bouligand dimension;
- The Box-counting dimension.

2. Applications in Geography

A. The Catastrophe Theory

In geography the theory of catastrophe can be used in the study on clouds (the edges are in reality the atmosphere's catastrophe regions) or in determinations of thresholds (critical values).

Case Study: Correlation between the fluid and solid flow, The Danube River, the Braila hydrological station.

The solid flow in suspension is in a close relationship with the fluid flow. With increase of the liquid flow, it is also realised the increasing of amount of silt, at beginning slowly, then after the overcoming of a critical value of liquid flow (5000m^3/s) it is accelerated fast and it is maintained until at overcoming another limit value (7000 m^3/s), after which the increasing rhythm diminishes again. (Figure no. 1)

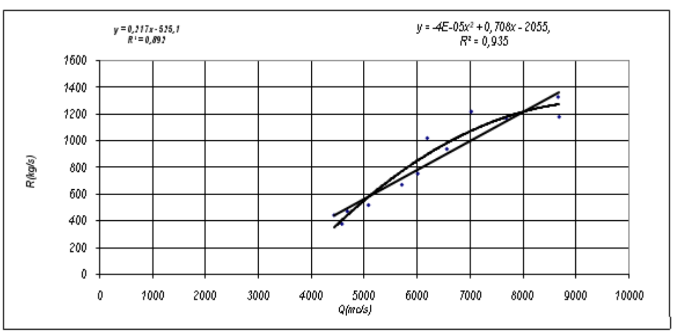

Figure no. 1. The Correlation between solid flow in suspension and liquid flow in multiannual means at Braila

At moving in suspension of silts, the particles are worn by current, being shared in the whole of its mass. The maintenance in suspension can be realised through the effect of turbulent pulsations of speeds. At moving in suspension the silts are fine, from the superficial erosion and come in a small measure in composition of riverbed. Therefore, the solid flow in suspension is determined by available solid flow entered in the determined section, the suspensions having smaller dimensions than transport capacity.

The presence of silts in suspension modifies the features of turbulent moving, determining the changes of speed distribution and miscarriages, the general form of river bed and the micro relief of river bed.

On the particles smaller than 0, 006mm there acts the decreasing speed and for the smallest act also the inertial and turbulence forces. [1]

B. The Dissipative Structures Theory

An example of Dissipative Structures is the one of convection cells. These were discovered experimentally by the physicist Henri Benard in 1900 and explained for the first time by the physicist Lord Rayleigh in 1916.

Case Study: The Convection Cells

The convection cells appear in a liquid expandable and homogenous layer, placed in a gravitational field and heated at the inferior part.

This situation is specific for asthenosphere (the upper mantle-coating of the internal structure of Earth, placed between 80km and 800 km depth), made from magma, a melt of silicates (Al, Si, Mg). The inferior part of asthenosphere has the average temperature over 1000 ^{0}C and the upper part about 450-500^{0} C, at contact with lithosphere.

Because the difference of temperatures exceeds the critical number of Rayleigh (>1000) [8], under the action of heat, the magma is moving, generating a convective structure.

Because the difference of temperatures is high enough, over 500 degrees Celsius, the Viscosity forces are defeated by convection forces, there resulting the appearance of order at a macroscopic scale. Convection cells have the essential role in dynamic tectonics, in the meeting zone of ascending currents, forming the subduction and/or collision zones. (Fig. no 2).

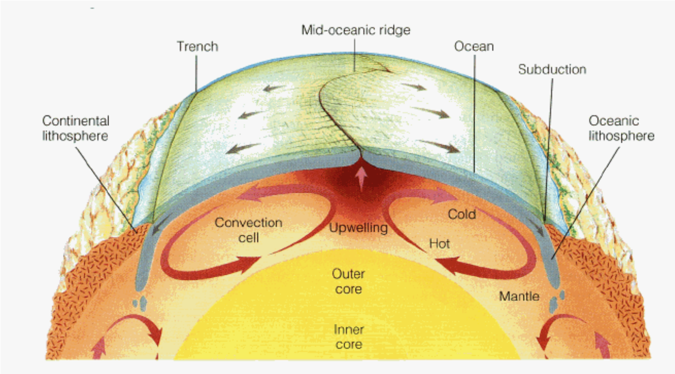

Figure no. 2 Mantle Convection Cell (from the Byrd Polar Research Center at Ohio State University)

C. The Deterministic Chaos Theory

The Atmospheric system is one from the illustrative systems where it manifests the deterministic chaos (a minor disturbance can generate changes which increase geometrically by the time.) In geography the using of deterministic chaos theory can be used successfully also in the study of slope crossing by a water, the base level for the course of the flowing water, the ascendant evolution of relief, the turbulence, the Whirling water in its flow.

Case Study: In 1963, Edward Lorenz developed a simplified mathematical model for atmospheric convection [4]. The model is a system of three ordinary differential equations now known as the Lorenz equations:

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \sigma(y - x),$$
$$\frac{\mathrm{d}y}{\mathrm{d}t} = x(\rho - z) - y,$$
$$\frac{\mathrm{d}z}{\mathrm{d}t} = xy - \beta z.$$

Where x, y, and z make up the system state, t is time, and σ, ρ, β are the system parameters.

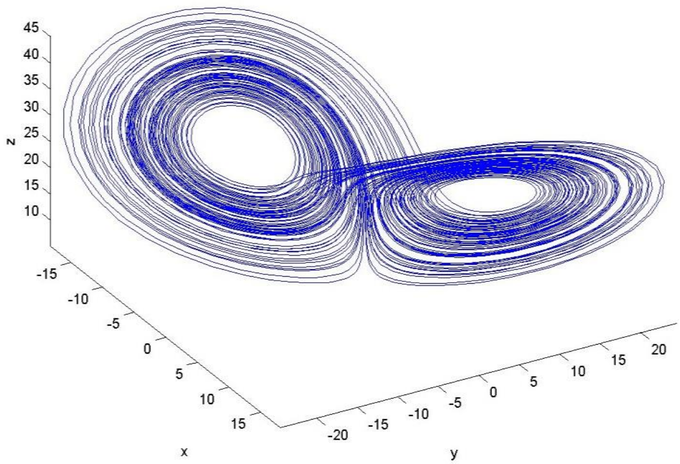

Figure no. 3 The Lorenz strange attractor

The Lorenz attractor is not a line or surface, but it is an intermediate figure, namely a fractal. Put in moving, the Lorenz attractor crosses the space around two "black invisible holes" (Fig no. 3). It jumps from an orbit to another in an "unforeseeable dance." The orbit of Lorenz attractor is never following precisely the same trajectory. It will go incommensurable close to anterior trajectory and immediately afterwards, the tiny difference of trajectory will become a major difference. In consequence, two trajectories which appear identical at a given moment, several moments later, these trajectories will orbit around two different centers. "The butterfly effect" emphasizes the Lorenz model. According to this effect, "a butterfly which flies in the South Hemisphere can bring about a hurricane in the North Hemisphere or a butterfly from Hong Kong can bring about a tornado in Texas." This effect is possible due to the fact that an infinite variation of primary conditions can have enormous consequences when the system is described by nonlinear laws.

Thus, the complex dynamic system, as is the atmospheric system, presents order, but it never repeats, being impossible to realise a precise prediction.

D. The fractal theory

Geography was one of the first fields which adopted the fractal theory. Mostly, the geographic forms are complex. They were described as serpentine, bacteria in growing, spiders, forms with twisted corners, DNA fragments [12]. The fractal analysis in geography is applied successfully in the analysis of shoreline, of relief aspect in ensemble, of clouds aspect, in the study of river basin [2], but also in analysis of distribution curves of the climatic, hydrologic parameters. [3]

Having at base the relation of Gray (1961), ($L = 1,4 * A^{0.568}$, where L=length of river and A=surface), B. Mandelbrot indicates that the rivers have a fractal dimension about 1, 2. The models created subsequently by B. Mandelbrot had emphasized the fractal character of rivers (Tarboton 1988). Based on contributions of Mandelbrot, many researchers are applying the fractal analysis in river study, such as Hjelmeflt (1988), La Barbera si Rosso (1989), Tarboton (1990), Veltri (1996).

Case Study: The fractal analysis of the Jijila river basin

There has been performed a fractal analysis of Jijila river basin because this is characterized through: complexity, unevenness, discontinuity, inconsistency in limits of Euclid geometry and is governed by nonlinear laws.

Based on the topographic maps from 1956 and 1998, at scale 1:50 000, one has realized a fractal analysis of Jijila river basin, for these two evolutive moments.

After the extraction of hydrographic network using QGIS 2. 0 [17] (figures no. 4-5), the image was converted binary using the ImageJ software in order to determine the fractal dimension. The resolution of images was chosen at value 3414 * 3194 pixels.

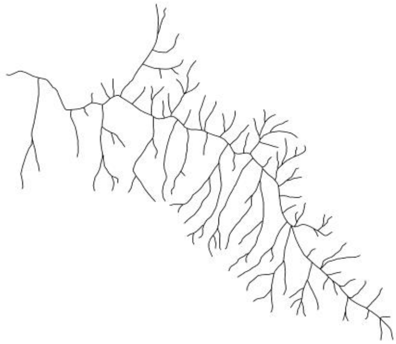

Figure no. 4 The Jijila river basin, the scale 1:50. 000 (1956)

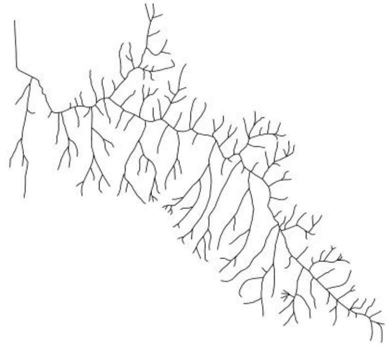

Figure no. 5 The Jijila river basin, the scale 1:50. 000 (1998)

The method of determination of fractal analysis was chosen the box-counting method. The box-counting method is suitable very well and in the situation of bidimensional heterogeneous and disordered structures, where the other methods commonly meet big difficulties in fractal dimension determination.

The Box-counting method is not capable only in determination of fractal dimension, but also allows to discern the possible scaling regimes, breaks, corresponding to different scaling properties for different scaling fields.

Box-counting method of fractal analysis, using the software ImageJ (National Institute of Health, Bethesda, USA), is widely used in the literature and is available free on the Internet [19], together with the FracLac plug-in [18] and with Fractal Analysis System 3. 4. 7 [16].

This method was defined by Russel et al. [12]; is the most frequently used and most popular method and it applies the following formula:

$$D_0 = \lim_{\epsilon \to 0} \frac{\log N(\epsilon)}{\log \frac{1}{\epsilon}},$$

where D_0 is the box-counting fractal dimension of the object, ε is the side length of the box, and N (ε) is the smallest number of boxes of side ε required to cover the outline of the object completely. Because the zero limit cannot be applied to natural objects, the dimension was estimated by the formula D_0 = d [6], where d is the slope of the graph of Log {N (ε)} against Log (1/ε). Using the Fractal Analysis System, the fractal analysis of Jijila river basin had increased from 1, 3572 (1956) to 1, 3884 (1998).

The increasing of fractal dimension is emphasized also by the analysis realised using FracLac under ImageJ:

- from 1, 5081 (1956) to 1, 5445 (1998) using the box-counting algorithm.
- from 1, 7182 (1956) to 1, 7186 (1998) using the Local Connected Fractal Dimension Analysis.

The increasing of fractal dimension reflects an increasing of dynamics of Jijila river basin, on the background of negative anthropogenic pressure. The increasing of fractal dimension is correlating very well with the increasing of the number of river segments in accordance with the Strahler system of stream order: for I order from 102 segments in 1956 to 167 segments in 1998. Also, it has increased the number of river segments by II order from 26 to 36 and by III order from 7 to 9.

Conclusions

The morphological theories are very different among them, being in reality the reflection of morphological diversity itself.

The morphological theories have an innovative role in geographic researches, firstly through its objective study - the world of forms - and then through its structural, qualitative and non –reductionist method.

Geography, as biology, has contact with continuous spatio-temporal data at the first sight, the purpose of the morphological theories being in this situation the specification of those spatio-temporal configurations which the stable and repetitive constituent elements can form, in a stable and repetitive way.

The morphological theories can be applied successfully in varied fields such as: the study on clouds, the determination of thresholds (the theory of catastrophe), the study of undercrust convection cells or atmospherical convection cells (the Dissipative Structures theory), the study of turbulence (the deterministic chaos theory) or the analysis of shoreline, of terrestrial relief aspect in ensemble, clouds aspect, in the study of a river basin, distribution curves of the climatic, hydrologic parameters (fractal analysis).

In geographic research the fractal analysis has a bigger impact because almost all geographical forms are fragmented, uneven, discontinuous, not being able to fit to the Euclid geometry.

The fractal dimension can be an important element for the evolution diagnostic of a relief form, degree of complexity or stability, but also in emphasizing the local differentiation and in intimation of evolutive trends.

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