SELF-ORGANIZATION OF GEOSYSTEMS. IS THERE AND TO WHAT EXTENT?

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ABSTRACT
Our study addresses the concept of self-organization of geosystems, arguing for its existence, how it manifests and what are the main forces that generate it. We then illustrate self-organization through its main traits and debate on how these features of natural spatial self-organization should be integrated into the process of spatial planning. We argued in favor of paradigm shift, in case self-organization concept would be assimilated in the study of geographical space organization. This paradigm shift would lead to a change of approach of the relation between people and society with the geographical space, which should be of subordination in relation with natural phenomena and processes. This new vision on the geographical reality can and may represent the framework for the seeds of new-oriented thinking on planning and designing development and future.

Keywords: self-organization, geosystems, complex systems, gradient, entropy

INTRODUCTION
Portugali (1999) stated that self-organization is the central property of, and a theory about, complex systems [1]. The demonstration and acknowledgement of systemic self-organization existence has been discussion topic that has proliferated in physics, chemistry and especially in biology (Boltzmann, 1886; Schrödinger, 1944; von Foerster, 1960; Ashby, 1962; Nicolis and Prigogine, 1977; Leonăchescu, 1992; Schneider and Kay, 1995; Jumarie, 1995; Bak, 1996; Skyttner, 2001, Parunak & Brueckner, 2001; Florea, 2005) scholars clarifying the most common concepts of complex systems, dissipative structures, entropy, self-organization and order of systems. In geography, the subject is still at the beginning and almost nonexistent in spatial planning practice, especially carried out by non-geographers planners. Our aim was to grasp the meaning of the complex concept of geosystemic self-organization through the qualities thoroughly defined in the last part of this work, advocating for a new perspective on planning to ensure the transition from sustainable to inclusive smart planning. Schwartzmann (1999) defined the self-organization of the biosphere formulating 6 theses on the biospheric evolution, of which the first two can be considered as foundation for our argumentation in favor of self-organized geosystems: 1. The biosphere is a complex adaptive system, adapting to changing external abiotic constraints but also self-adapting and self-selecting and 2. The biosphere is a self-organizing complex whole. The interpenetration of its parts and its whole includes the nonlinear interaction of the parts, its network of positive and negative feedbacks, the continual reshaping/rearticulation of the parts by the whole [2]. As Parunak & Bruckner (2001) pointed out, humans in general, seek to impose structure and organization on the world around them and they have to struggle to maintain the

desired structure [3], we could then assert that man-made structures resulted from spatial planning procedures should be adapted to the complex self-organizing geosystems. Logically, spatial planning must derive from the opportunities provided by the self-organization of geosystems, be consistent with it and not contradict it. But, for this to happen, first of all it must be shown that geosystemic self-organization processes occur in the geographical space and that geosystems are the product of self-organization processes.

SOME CONSIDERATIONS ON SELF-ORGANIZATION

Systemic self-organization has been a widely debated concept in physics, chemistry and especially in biology. This concept has been approached rather recently in geography, transforming into a new concept, that of self-organization of geosystems. The issue of self-organization of natural elements, such as: river meanders (Hooke, 2007), dunes (Bishop, 2010) or ecosystems (Stavi et al, 2015) has been addressed lately proving them as self-organized complex systems that develop according to a certain pattern (self-management and self-repair) and proving resilience, high level of adaptability against external factors that could produce disequilibrium. The emergence of self-organized structures is a natural response of a system's attempt to resist and dissipate energy gradients applied from outside and that would unbalance the system. Therefore we are witnessing the emergence of Schrodinger's notion of *order from disorder* and the formation of dissipative structures. The concept of dissipative systems developed by Prigogine (1977) is applicable in physical and chemical systems in disequilibrium and it describes the processes of emergence and development of complex systems while pointing out that non-equilibrium may become a source of order and that irreversible processes may lead to a new type of dynamic states of matter. Thus, not only that the processes of dissipative systems are compatible with the second reformulated principle of thermodynamics, but it is expected that dissipative systems should occur if conditions and energy gradients existed [4]. Here we can take for example the autogenic organization pattern of river meanders described by Hooke (2007) who demonstrated that complex systems such as channel forms will always adjust to a new equilibrium no matter the morphological changes determined by climate change, land-use change, water-control, or other external inputs [5]. Based on the theory of equilibrium and adjustment, all changes determined by extrinsic factors are absorbed and adapted to by the complex system due to the self-organization quality prevailing in the internal dynamics of the geosystem.

The starting point for explaining the capacity of matter to self-organize in the geographical space is the potential field. The potential field is the differentiated distribution pattern of matter within the geographical space as a result of structuring processes of planets and other physical forces that activated during the geological time (gravitation and internal earth's heat). The synergic action of these two forces have determined most of the actual configuration of the geographical space which has been subject to the local modeling forces (water, air, biosphere) with their specific physical and chemical properties (temperature, pressure, flow, flow speed, chemical reactions speed). This primordial structuring has generated complex potential fields (based on gravitation, radiation, heat, concentration, dispersion, distribution, etc.) in the geographical space. Then, we cannot speak about isomorphism but of poliphormism, which subsequently generates various types of potential fields, based on which matter, energy and information flows are produced. It is these differentiations and specific potential fields that generate various flows and set the foundation of geosystemic self-organization. To causally explain geosystemic self-organization we first have to analyze the generation of flows within a potential field based on the argument Sepehr (2014) brought, according to which non-equilibrium systems are maintained in a state away from thermodynamic equilibrium by the steady injection and transport of energy [6]. The energy gradients or potential difference generate processes and subsequently self-organization. No process in nature can exist or develop without the existence of differences of potential. This is the primary triggering factor of self-organizing systems. There is a wide range of potential gradients that generate as many geosystemic self-organized structures, and based on their influence towards the emergence of self-organized geosystems, we mention the gravitational, radiative-caloric, thermal, baric, geochemical, hydrological, biogenic, and entropic gradients.

In this respect, to be able to argue in favor of geosystemic self-organization we present the theory of equipotential fields proposed by Leonăchescu (1990) later extensively analyzed by Zotic (2005) [7, p. 67]**.** If equipotential surfaces $\Pi_1, \Pi_2, \Pi_3 \dots \Pi_n$ are accepted and it is agreed that: $\Pi_1 < \Pi_2 < \Pi_3 < \dots < \Pi_n$, the results will materialize by releasing a flow (Φ) that will spread from the large equipotential surfaces towards the small ones (Fig. 1).

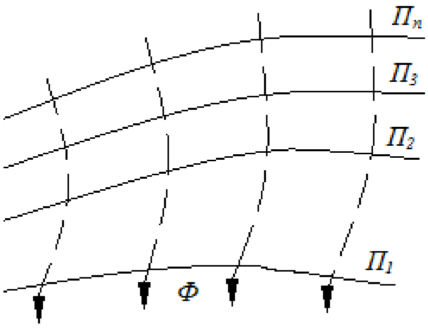

Fig. 1. Potential difference and direction of flows [8].

From this axiom we can conclude that: "*processes cannot exist without any potential difference*" and further deduce the "*law on the vectorization of processes using the potential gradients*". Thus, *flows resulting in a potential field are naturally following the gradients of the greater potential, namely in the direction of the normal to the equipotential surfaces* [8].

The direction of generated flows (Φ) is reverse to the upward direction of the normal (AB) in the direction (ñ) to equipotential surfaces ($\Pi_1, \Pi_2 \dots \Pi_n$) (Fig. 2).

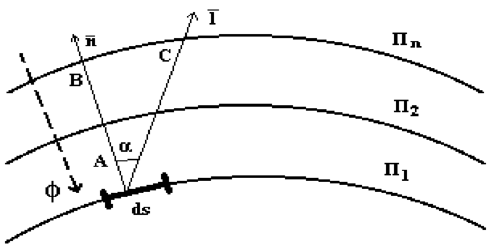

Fig. 2. The model of vectorization of flows in a potential field [8].

The movement of natural flows consistent with potential gradients reflects the specifics of the Second Law of Thermodynamics, which postulates that "*systems evolve in the direction of least resistance with minimum energy consumption*". As a general law of nature, it directs the flow of natural processes in the direction of least resistance, which corresponds to the potential gradients (in the opposite direction of the normal to the equipotential surface) and it is particularly important for the control of spatial flows under optimum functional conditions. The production of substance and energy flows, their orientation consistent with potential gradients, lays the ground for all systemic structures, and of processes of transformation and differentiation. The probability of flow production in other directions, for example in the (ī) direction (AC flow in the direction of ī) becomes smaller as the angle (α) increases, in accordance with the *Principle of minimum energy*. [8]

$$\frac{\partial \Pi}{\partial l} = \frac{\partial \Pi}{\partial n}\cos\alpha; \frac{\partial \Pi}{\partial l} = |\Delta \Pi| \cos\alpha \quad [8]$$

The diagram below shows this flow variation (see Fig. 3).

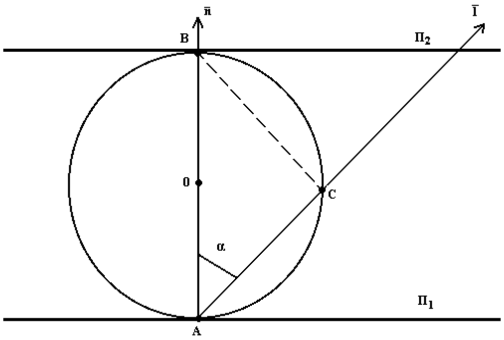

Fig. 3. Variation of flow production probability in correlation with the deviation from the normal of equipotential surface [8].

If the diameter of the circle AB = |ΔΠ| then:

$$\frac{\partial \Pi}{\partial l} = AC = AB\cos\alpha \quad [8]$$

For an angle α = 90º flows become null (along an equipotential surface flows are null). Getting a flow in the (ī) direction equal to the flow from the (ñ) direction (of potential gradients), it involves additional energy consumption, which increases along with the increase of α angle. In case of natural systems there are usually multiple potential differences acting simultaneously and generating processes. Potential differences interfere, overlap and are interdependent. If several processes, generated by the potential difference, act simultaneously in the same place, at the same time, then processes couple and form complex loops of positive and negative feedback. These were thoroughly analyzed in "*The theory of coupled natural processes*", concluding that "*all systemic natural processes are deeply interconnected and in case of denying a natural law, the system is condemned*" [9].

Thus, we could define geosystemic self-organization as being equivalent to the product between the difference in the potential field and the amount of entropy existing in the environment at some point:

$$So = \Delta\Pi * S_{t-1}$$

where:

So – the level of self-organization

ΔΠ – the difference in the potential field

S_{t-1} – the amount of entropy existing at some point in the environment

The difference in the potential field (ΔΠ regulates the trajectory and structural complexity of self-organizing systems. Thus, if:

ΔΠ > 0 – it generates self-organization;

ΔΠ≥1 – it generates multiscalar self-organization;

ΔΠ ∞ - it annihilates entropy and generates pure self-organization, where ΔΠ ∞ = E in which case energy is the pure form of self-organization.

Jumarie (1995) stated that the level, the grade of the organization capability of the system would be directly characterized by the constraints which act on it [10]. This statement opens such a wide field of forming and developing self-organized systems not only physical, chemical, biotic but also geographical, speaking about geosystemic self-organization in the geographical space. The constraints of geosystemic self-organization are generated by the decrease in potential difference, which subsequently determines the uncontrollable action of entropy that in this case can annihilate any form of self-organization. Otherwise, once there is a normal potential difference (ΔΠ≥1) or even accentuated over the entropy level, this can first annihilate entropy and generate negentropy, and subsequently support the multiscalar self-organization processes.

THE MAIN TRAITS OF GEOSYSTEMIC SELF-ORGANIZATION

Geosystemic self-organization identifies with the particular features of the geographical space, individualizing it in relation with sociosystems and man-made actions that influence and alter the natural landscape and environment and determine its functionality on the whole. Geosystemic self-organization in a clearly defined space, acting as the relationship field between all components of the geographical space, identifies with several main particular features, such as: unity, zonality cyclicity, limitation, material and spatial polyphormism, dynamics, spatial discretion, spatial continuity, time-structure, and entropy [7, pp. 27-29]. Trying to further our knowledge and highlight the distinctive functionality and behavior of geosystems we focused on the diverse expression of these features and analyzed them in relation with sociosystems.

1) Unity. Unity reveals from the interdependent relationships among all the subcomponents of the geographical space, along with the man-made systems created within through planning and development measures and actions. This means that there is no independent action, phenomenon or object functioning within the geographical space. If unity not considered, the newly organized sociosystems would be marginalized, isolated or even eliminated from the spatial structures. Thus, any newly implemented anthropogenic structure would be connected to one or more geosystems, even only by its localization within the geosystem and/or its influence area. These leads to the fundamental idea that the projection of anthropogenic systems must ensure the possibility of their integration into the geosystems and they should not be perceived as foreign bodies by the latter and consequently be subject to destruction and annihilation processes.

2) Zonality. It represents the expression of the diversity of geographical space. This diversity is given by the unequal distribution of solar radiation on the earth's surface, which creates various climatic zones and subsequently other categories of areas: bioedaphic, agricultural, landscape, economic, demographic, etc. This diversity is what allows for the relationships between geosystems and the power of self-organization. We find this complex diversity everywhere in the geographical space, entailing differences in structure, functionality, and size of geosystems. As parts of the unity of the geographical space, sociosystems have to adapt and adjust to these differentiations so as to be able to integrate functionally and organically. In case of the sociosystemic components that do not comply with this zonality, they base on the overconsumption of negative entropy and „free" energy which they have due to the destruction of other geosystems or by forcing others to produce a surplus of negentropy.

3) Cyclicity. This is one of the most general laws that rules the organization of geographical space, at all ranks, with all its components, including the biosphere and sociosphere. This configures and optimizes the integration of sociosystems into the geosystems, regulating the type, form and manner through which planning would be optimal without creating conflicts with the geosystems. Going beyond these limits sociosystems can either destruct the geosystems or severely affect them, by generating positive feedback in order to rebalance the thermodynamic equilibrium, if the geosystem proves able to achieve it in terms of size, structure and strength. By acknowledging and understanding cyclicity it becomes natural for the sociosystems to organically integrate into the geosystems and develop benefitting from the structural and functional advantages of geosystems for a long time. In case planners do not factor cyclicity in planning and designing the sociosystems, the positive entropy will always increase. Thus, to counterbalance the negative effects, there will always be a larger consumption of „free" energy.

4) Limitation. The geographical space is limited, which essentially means that organization and planning of any other overlapping sociosystems must consider the limited availability of time, space and resources within the geosystems. Unorganized and oversized man-made actions and facilities eventually invade the vital space of other geosystems triggering their dismantling or functional and structural decrease. Thus, all categories of social systems should be supple, enough „elastic" and not oversized to be able to adapt to the requisites of the geosystems and avoid their collapse in case geosystemic functional parameters change. And, how can this be done? By organically developing in relation with unity, zonality, ciclicity and the limitation of the geographical space and its geosystems.

5) Material and spatial polyphormism. Another major advantage that geosystems provide is the variety of matter as form and structure, which in the end favors the emergence and development of life and sociosystems while dismissing uniformity and use of standardized solutions in spatial planning. The spatial diversity of geosystems is revealed by the different, unique and unrepeated chemical, physical conditions under which matter is organized in simple or complex structures. In case of a restrictive environment though, diversity could not be possible nor the geosystemic self-organization. This material diversity has however opened the way for artificial synthesis practically invading the environment with foreign elements that prove to become pollutants due to their long-term decomposition period. This environmental pollution with high synthesis components represents the transfer of supplementary positive entropy that perturbs the functionality of geosystems even more. The best way to follow is not to give up the artificial components and technology but to synthesize environmentally friendly and easily degradable components. On the other hand, matter ends not to be uniform due to the considerable influence of permanent or temporary forces and factors that act within the geosystems (i.e. gravitation, Coriolis force, geographical zonality, cyclicity of solar energy on the active surface) and also due to zonality or azonality, symmetry or asymmetry found in the geosystem. The variety of matter and space can almost completely influence the diversity of socioeconomic systems, any man-made structures having to adapt to the environment and not vice-versa.

6) Dynamism. Geographical space and its geosystems are dynamic in time, continuously altering their structural and functional self-organization at all holarchy levels. However, the most frequent and visible alterations are registered and noticeable at local level, since it takes them historical and geological times to be globally visible. Hence, any newly designed and implemented anthropogenic structure must be capable to adapt to the dynamics of geosystems. If rigid, they are subject to self-exclusion and functional destructuring. By maintaining rigid anthropogenic structures with high management costs proves not to be viable on long and medium term.

7) Spatial discretion and continuity. The geographical space is a spatial continuum made of interrelated geosystems between which there is no void, even though some of the geosystems are rather discreet. Spatial planning should consider them all to avoid the most frequent dysfunctions that would appear in the functionality of man-made systems triggering disequilibrium within geosystems. Thus, each geographical area consists of all kinds of geosystems and their respective relationships, of a certain density, spatial concentration and polarization with functions and influences at a certain moment in time. This implicit spatial continuity of geosystems of which man used to be an organic part once, is currently disturbed by sociosystemic discontinuities. These discontinuities have radicalized the confrontation between geosystems and sociosystems both claiming the same space for their development. Then, the organic development of sociosystems should imply the harmonization of relationships with all categories of geosystems, both visible and discreet, and not presume that if something is not visible then it does not exist and subsequently cannot affect us, eventually failing to consider it. Yet, being the last on the chronological scale and the last appeared in the geographical space, sociosystems seem to overlook their only secondary rank and their status of subsystems. This status cannot be deleted from „the memory" of geosystems that are claiming and will always claim their first rank until dismantling, while sociosystems still do not accept their subordinate status implicitly imposed. The self-acceptance of this status should make „peace" between the two types of systems and should pave the way towards organic development**.** The moment human society has assumed the status of „creator" it implied sine qua non the full perception of this reality and the creative act accordingly.

8) Order and time-structure. The geographical space is fully ordered and organized, which is a state imposed by the uninterrupted process of geosystemic self-organization. This order and this organization is not just momentarily but permanent, and subsequently timely transferable. Therefore the level of organization is a time function, always dependant on the control variables of organization (level of energetic flow within the geographical space at a certain moment as well as the external and internal perturbing factors). And the fact that they permanently generate order and subsequently negative entropy (negentropy) for our use, thus permanently assimilating the positive entropy, what geosystems offer us in designing development has to be seen as a major advantage. Without this ability of continuous geosystemic self-organization, the geographical space would rapidly „fill" with entropy and all of the systems would eventually stop working. The problem is how much positive entropy we produce, especially due to the extensive development of sociosystems, and if this quantity can still be assimilated and converted into negative entropy by the geosystems, since the rhythm of destructuring has dramatically increased at a global level. Therefore, we should take on the organic development of sociosystems in accordance with the time-structure of geosystems, because, nature cannot be rushed forever!

9) Entropy. The level of entropy expresses the level of structural order of the geographical space and it changes according to the number of spatial elements and differently from their level of order. Thus, „*the higher the number of functional connections needed between components and elements is, the higher the level of order is, and the smaller the occasional perturbing stressful connections are*" [7, p. 9]. Thus, by increasing structural complexity within the geosystems we fight against high entropy level. Subsequently, in case of the same energetic availability, the positive entropy released by the sociosystems in the geosystem is then counterbalanced by increasing the self-organization level. However, the major issue appears when sociosystems invade the vital space of geosystems, given that any increase in the organization complexity implies taking over space from the geosystems. We thus further agree with the conclusion that: "*the paradigmatic sense of the organization of spatial structures as dissipative geosystems, be them local or general, is that of degradation of the available energy (be it external – solar or internal – telluric and of earth rotation) up to thermodynamic equilibrium. The very existence of geosystems is determined by the existence of „free energy", energy that by executing the mechanical work can lead to the organization and existence of matter in organized (geo)systemic structures* [7, p. 27]. Thus, the goal of geosystems in the geographical space is to dissipate the free energy that created them (according to the second Law of Thermodynamics). The typology, structure and complexity of the organization of dissipative geosystems are determined by the amount and type of free energy available within the geographical area at a time and at a certain holarchy level. The living matter is also organized in dissipative structures (biological and ecological) which are far from thermodynamic equilibrium, and which fulfill the same purpose – that of dissipation of free energy to equalize the potential - in accordance with the laws of thermodynamics.

CONCLUSIONS

The entire geographical space is located in an energetically differentiated field that generates complex and various forms of self-organization, starting from the local self-organization forms, expressed through river basins, slopes, shorelines or ecosystems up to the very universal self-organization expressed through the great geospheres. Basically, all that we see and consider natural geosystems, they are self-organized geosystems. Man-made geosystems are partially self-organized up to the level at which they subtract from the action of natural forces and energies, at which level spatial planning and planning begin take over.

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