ARE HUMAN SETTLEMENTS ECOLOGICAL SYSTEMS?

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Abstract. Even though "human ecology" is an old and often used concept, many debates are present in the ecological literature whether human settlements are ecological systems or not. The paper analyses the evolution, structure and functions of human settlements in relationship to their scale. The results indicate that, despite of the altered structure and functions resulting from the presence and activities of the dominant human species, human settlements are ecological systems, ranging based on their size from "ecosystems" to "complexes of ecosystems" (landscapes).

Keywords: urban ecosystem, functional structure, biodiversity, human species, scale.

Rezumat. Sunt aşezările umane sisteme ecologice? Deşi termenul „ecologie urbană" datează de ceva vreme şi este des folosit, în literatura de specialitate din domeniul ecologiei sunt prezente multe dezbateri privind posibilitatea de a considera aşezările umane sisteme ecologice. Lucrarea analizează evoluţia, structura şi funcţiile aşezărilor umane în funcţie de scara acestora. Rezultatele arată că, în pofida modificării structurii şi funcţiilor datorită prezenţei şi activităţii speciei umane dominante, aşezările umane sunt sisteme ecologice, situate în funcţie de mărime pe nivelul ecosistemelor sau complexelor de ecosisteme.

Cuvinte cheie: ecosistem urban, structură funcţională, biodiversitate, specia umană, scară.

INTRODUCTION

Analysing different definitions of "systems", it can easily be seen that the concept describes a sum of elements working together as a whole (BOTNARIUC & VĂDINEANU, 1982); the elements are objects and their relationships (IANOŞ & HELLER, 2006). Other authors consider that systems are functional structures (IANOŞ, 2000; VĂDINEANU, 1998, 2004; PETRIŞOR, 2008). The later view expands the first one showing that the structure (interrelated elements) is adapted to its functions in a double sense: functions modify the structure, and a certain structure can carry only one or more specific functions (PETRIŞOR, 2011). This feature characterizes mechanical systems (e.g., a car must have a certain structure in order to function as a vehicle), living systems and other systems too. In ecology, Tansley's definition (TANSLEY, 1935) identifies the two components of an ecosystem: the living component (called in the British literature "biocoenosis" and in the American one "community") and the non-living component (biotope).

While "urban ecology" is said to trace its roots in the 50's, but its first dated use was during the 1968 symposium "Challenge for survival in megalopolis" (PETRIŞOR, 2008). Since ecology embraced the systemic theory, urban ecology followed the same pattern and authors started using the term "urban ecosystem". In 1997, a new journal, "Urban Ecosystems", was started in the Netherlands. The first Editorial defines the urban ecosystem as a particular type of ecosystem (based on Tansley's view), where man is the "*keystone species controlling ecosystem structure and function*" (WALBRIDGE, 1997).

The dominant presence of humans in their settlements, and the control exercised over the structure and functions of ecosystems made many authors reluctant in accepting the fact that human settlements are ecosystems (METZGER, 1994; MCINTYRE et al., 2000; REES, 2003; PICKETT & GROVE, 2009; COLLINS et al., 2012), while others seem to embrace the new concept (CRISTEA & BACIU, 2000; EUROPEAN ENVIRONMENT AGENCY, 2010). One of the underlying causes could be the lack of interest for carrying out research in inhabited areas (MARRIS, 2009; CORBYN, 2010; COLLINS et al., 2012). Other authors underline structural differences, particularly related to biodiversity (CRISTEA & BACIU, 2000; SAVARD et al., 2000; EUROPEAN ENVIRONMENT AGENCY, 2010; ŠUSTEK, 2011, 2012; RIDICHE & BĂLESCU, 2012) or altered biotope conditions due to human activities (GAVRILESCU, 2011; CORNEANU et al., 2012), functional differences (BOLUND & HUNHAMMAR, 1999; CRISTEA & BACIU, 2000; DECKER et al., 2000; LUNDHOLM, 2006), or scale (METZGER, 1994; SAVARD et al., 2000; CLERGEAU et al., 2006).

Especially in regard to the scale, based on Gaia theory (LOVELOCK, 1979), other authors assimilate the city, despite of its size, with an organism, and discuss about the "urban metabolism" (DECKER et al., 2000; CRĂCIUN, 2008; GOLUBIEWSKI, 2012), up to identifying "normal" and "pathological" forms of it (STAN, 2011). At the opposite pole, other authors consider that cities are situated at the level of "complexes of ecosystems" or "landscapes" (METZGER, 1994; CLERGEAU et al., 2006; PETRIŞOR & PETRIŞOR, 2008; PETRIŞOR, 2010; 2011).

The aim of this study is to discuss the structure and functions of human settlements from an ecological perspective, in order to see whether they can be assimilated to ecological systems.

EVOLUTION

During the historical evolution, human settlements were first similar to what we call "rural" nowadays. Gradually, some of them became "urban areas". Therefore, the anthropization process consists of a first transformation of natural systems into rural systems, and later into urban systems. The presence of humans is more intense in cities, resulting into additional elements that exacerbate the difference between natural and man-dominated systems along the gradient natural – rural – urban; for this reason, the conceptual model displayed in figure 1 shows a transversal line symbolizing the balance between natural and anthropic elements, leaning towards the latest in urban systems.

In this context, it is noteworthy mentioning that the definition of "urban" areas has a different meaning for ecologists, economists, sociologists, psychologists or planners (MCINTYRE et al., 2000); in general, the United States definitions are based on the density of human population, while the European ones focus on key indicators (such as educational or cultural infrastructure, but also from other social or economic areas) (PETRIŞOR, 2008).

During the process, man-dominated systems couple functionally to the natural ones. Resources are taken directly or from agro-ecosystems, a component of the socio-economic system, using technology. Energy is present in fertilizers, pesticides, soil and green space works. Humans change the structure of geographic spaces. Altered biogeochemistry and loss of biodiversity decrease the stability of natural systems and increased their dependence on the man-dominated ones (COLLINS et al., 2012). The process is assessed using the concept of eco-energy – initial energy, before conscious human interventions (IANOŞ, 2000); the concentration of population and economic activities consume primary eco-energies as the level of anthropization and complexity of geosystems increase. Eco-diversity and geodiversity increase at the expense of biodiversity (IANOŞ et al., 2011; PETRIŞOR & SÂRBU, 2010).

STRUCTURE

Even though the structure of natural, rural and urban systems does not differ in terms of the names of components, detailed variation is visible along gradients of anthropization (ŠUSTEK, 2011; 2012). In the introductory section, the living component of an ecosystem was called in the British literature "biocoenosis" and in the American one "community". The latter term can produce confusions, especially when authors discuss about "mammal communities" or "bird communities". The biocoenosis consists of all plant and animal species of an ecosystem (BOTNARIUC & VĂDINEANU, 1982); "community" can be used equivalently or in order to refer to a specific group. Especially in man-dominated systems, fragmentation, loss of biodiversity and functional disturbances induced by human activities determine the assembly of species to work as a group of "communities' instead of being a whole.

The overall biodiversity of species is lower than in natural systems, resulting into shorter food webs, and into the fact that man-dominated systems are "incomplete" and the reduced biodiversity prevents the specialization of its components (PETRIŞOR, 2008). However, some groups (particularly invertebrates) are favoured. Man replaces species in time introducing new ones or eliminating the existing ones directly or indirectly; as a result, the entire biocoenosis is changed over longer periods. Researchers have found a variety of niches and habitats even in urban areas (PETRIŞOR, 2008; 2010). They are inhabited by species seeking for human habitats – so-called hemerophilous species, including the ones that are found only in these areas (synanthropic), indifferent to the presence of humans (hemerodiaphore) (NOBLET, 1994, 2005; PETRIŞOR, 2008, 2010). From a different viewpoint, man-dominated systems include many ubiquitous and opportunistic species (the latter can be eventually favoured by shifting conditions due to human activities), and to a lesser extent by random species (CLERGEAU et al., 2006; PETRIŞOR, 2008, 2010). In addition to them, people bring allochthonous species, some even invasive (PETRIŞOR, 2008; COLLINS et al., 2012), and proliferate the domestic species (PETRIŞOR, 2008). Most often, the species characterizing natural systems from the same region are confined to the green spaces (PETRIŞOR, 2008; EUROPEAN ENVIRONMENT AGENCY, 2010). In a spatial perspective, the type of biodiversity (α, ß etc.) can be correlated with the size of the human settlement and described in relationship with the diversity of habitats, land use or cover, biogeographical region, etc. (PETRIŞOR, 2012a). However, if biodiversity is diminished, the diversity of man-generated structures is increased with the level of anthropization.

The biotope is altered too. Over long periods of time, even the geography is changed by modifying water courses and through the pressure exercised by the increased mass of constructions. The soil is removed or covered by asphalt, or, if it exists, does not have too much to offer to vegetation (PETRIŞOR, 2008). Microclimate is affected especially by urban areas, which become heat islands, particularly during the warm season (CHEVAL et al., 2009; EUROPEAN ENVIRONMENT AGENCY, 2010; COLLINS et al., 2012) due to the alteration of biogeochemical cycles, such as the water circuit discussed in the next section. However, these changes are the least evident. What becomes obvious in man-dominated system is the presence of infrastructure (built capital, physical capital) and pollutants (METZGER, 1994; REES, 2003; PETRIŞOR, 2008, 2010; PICKETT & GROVE, 2009; GAVRILESCU, 2011; CORNEANU et al., 2012). All these are influenced by what could be called the "human mind", and assessed by psychological, social, anthropological, cultural structures, resulting into the socio-economic, political, legislative and administrative conditions that set their fingerprint over the layout and operation of human settlements (BOŞTENARU, 2005; PETRIŞOR, 2008, 2010; PICKETT & GROVE, 2009).

The separation between man-dominated systems and the adjacent ones is naturally done by ecotone areas. Researchers have identified urban fringes as having the same function (STAN, 2009; COLLINS et al., 2012). However, based on its social analysis, other authors consider that urban fringes have a separating role instead of a joining one, and certainly do not account for the productivity of the two ecosystems (PETRIŞOR, 2012b).

Figure 1 displays the components of human settlements in this view, as well as their connections. Based on the definition of territorial systems (IANOŞ, 2000) and ecological standpoint (TANSLEY, 1935; BOTNARIUC & VĂDINEANU, 1982; VĂDINEANU, 2004; PETRIŞOR, 2008, 2010, 2011), the figure has four areas, corresponding to the division between "natural" vs. "man-dominated" and "living" vs. "non-living".

FUNCTIONS

Again, in theory man-dominated systems carry out the same functions as the natural ones: biogeochemical cycles and self-regulation. Nevertheless, they are radically changed. Biogeochemical cycles are disturbed, often resumed to a straight, unidirectional linear flow (CRISTEA & BACIU, 2000; PETRIŞOR, 2008). Some of the examples relate to the water circuit: in cities, water reaches the sewerage system, and is taken outside; consequently, urban planners find a strong need to create artificial water bodies or courses, or at least fountains (CRISTEA & BACIU, 2000; DECKER et al., 2000). Also, the input of natural energy is diminished due to the scarcity of primary producers. Consequently, man-dominated systems need external matter and energy sources, found in the natural ones (CRISTEA & BACIU, 2000; DECKER et al., 2000). From this perspective, they become "energetic parasites" of these systems (VĂDINEANU, 2004; PETRIŞOR, 2008). The dissipative character is more evident in man-dominated system than in the natural ones, due to the structuring interventions of humans (REES, 2003; PETRIŞOR & SÂRBU, 2010).

Moreover, the food levels can be seen as part of an entire hierarchy of levels, starting with the traditional trophic ones, derived from physical consumption of food, and continuing with technotrophy (consumption of energy and resources by technology) and nootrophy (their consumption in the activities supporting human development, such as research, education, management, administration etc.) (IANOŞ, 2000; REES, 2003; PETRIŞOR, 2011).

Self-regulation is inhibited by the loss of biodiversity (CRISTEA & BACIU, 2000; EUROPEAN ENVIRONMENT AGENCY, 2010) and, in general, by the control exercised by humans. If the evolution of general systems is described by concepts like "succession" (BOTNARIUC & VĂDINEANU, 1982; DECKER et al., 2000; MCINTYRE et al., 2000), "panarchy" or "adaptive cycles" (HOLLING, 2004; VĂDINEANU, 2004), the model proposed for the human settlements is a spiral, suggesting the fact that humans change the characteristics of their system through each intervention (IANOŞ et al., 2011; PETRIŞOR, 2011). Nevertheless, from the succession standpoint, man-dominated systems are young, immature (PETRIŞOR & IANOŞ, 2011).

Functions are also affected by the action of natural laws. One of the limiting ones is the "minimal law', meaning that many parameters required for the normal life of species are reduced to a minimum and act as constraining factors. Mitscherlich's law, describing the decrease in intensity of the favourable action of some factors as their dosage increases, explains the need to use extra-energy in order to maintain natural areas like urban green spaces (PETRIŞOR, 2008).

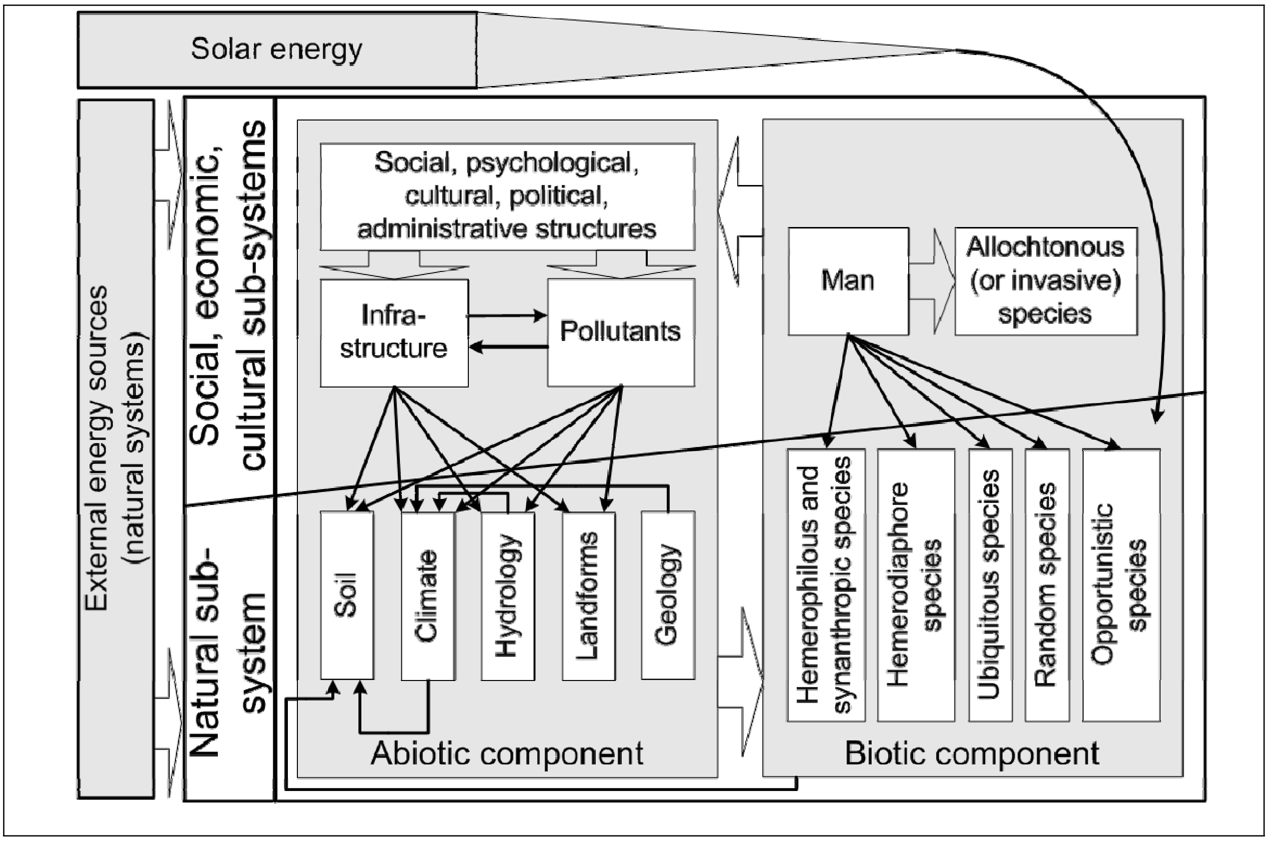

Figure 1. Conceptual model of the structure of man-dominated systems in relationship to their functions.

Last but not least, specific functions oriented by the role of human settlements (military, commercial, capital etc.) influence their structure and functions seen from an ecological perspective, resulting into diminishing or favouring some of them, but also in increased pollution (PETRIŞOR, 2008; PEPTENATU et al., 2010, 2012), depending on the attitude towards the environment (IANOŞ et al., 2009).

Figure 1 displays the functional characteristics of human settlements, with a particular focus on energy. The focus is determined by the relationship between energy, land use, climate change and composition of biocoenoses, and its consequences over the planning process (DALE, 1997; BOLUND & HUNHAMMAR, 1999; DALE et al., 2009, 2011; MEIŢĂ et al., 2011; PETRIŞOR et al., 2011; PETRIŞOR, 2012a). Land cover refers to a biophysical interpretation of what lies on the ground surface (JENSEN, 2000), while land use indicates its use by human communities or a more detailed classification of natural systems (PETRIŞOR et al., 2010).

SCALE

Apart from the diversity of habitats, human settlements are, from the standpoint of land cover and use, a mosaique of vegetated areas (pastures within rural areas, green spaces within the urban ones), semi-natural areas (parks, green spaces, encroached portions of natural systems), human-built infrastructure and occasionally other elements. For this purpose, some authors suggest that, on a scale starting with ecosystems, continuing with the complex of ecosystems or landscapes and ending with the planetary system – ecosphere, large human settlements, especially cities, through their complexity exceed the first level approaching the second (METZGER, 1994; BOLUND & HUNHAMMAR, 1999; CLERGEAU et al., 2006; PETRIŞOR, 2010, 2011).

At the next spatial level, man-dominated system and adjacent infrastructure (roads) form the socio-economic system, expanding over the natural ones. The characteristics of its dynamics are: (1) spatial expansion by substituting, simplifying and fragmenting natural systems; (2) increase of inner complexity and fluxes of resources taken from natural systems and pollutants dispersed into them; (3) linearization of biogeochemical cycles; (4) accumulation of waste; and (5) regionalization and globalization through increased connectivity (VĂDINEANU, 1998).

CONCLUSIONS

The paper aimed to answer the question whether man dominated systems, particularly human settlements, can still be considered ecological systems. Many differences have been found between the extremes of an evolution scale starting with natural system, including the rural systems and ending with the urban systems, in order to reflect the degree of anthropization and consumption of natural energy and resources, but also between the three levels. The differences are found in their structure (loss of biodiversity and presence of man-induced infrastructure and pollutants in man-dominated systems) and functions (linearization of biogeochemical cycles, increased dependence of human activities, energy and resources of other systems, and low self-regulation capacity of man-dominated systems). Despite of these differences, the essential components of ecological systems are still present. Based on this, human settlements can be considered ecological systems with a different homomorphous model, situated, depending on their scale, at the level of "ecosystems" or "complexes of ecosystems" (landscapes).

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