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System aspects research of ecosystem services in the economy for sustainable development

Systemowe aspekty badania usług środowiska w ekonomii zrównoważonego rozwoju

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Abstract
One of the strategies to develop a coherent and consistent approach to the economic category of ecosystem services in the economy for sustainable development is to adopt a systemic perspective. The aim of this paper is to present original system aspects in the research on ecosystem services in the emerging economy for sustainable development. The paper analyses the concept of a system, properties of dynamical systems, evolution of systems, systems approach in the perspective of the sustainable development paradigm, and assumptions of the systems research on ecosystem services in the economy for sustainable development.

Key words: sustainable development, economy for sustainable development, environment, ecosystem services, systems, systems theory

Streszczenie
Jedną ze strategii umożliwiających wypracowanie spójnego i jednolitego podejścia do ekonomicznej kategorii usług środowiska w ekonomii zrównoważonego rozwoju jest przyjęcie w badaniach nad nią perspektywy systemowej. Celem opracowania jest autorskie przedstawienie systemowych aspektów badania usług środowiska w tworzącej się ekonomii zrównoważonego rozwoju. W opracowaniu przeanalizowano pojęcie systemu, właściwości systemów dynamicznych, ewolucję systemów, podejście systemowe w perspektywie paradygmatu zrównoważonego rozwoju i założenia systemowego badania usług środowiska w ekonomii zrównoważonego rozwoju.

Słowa kluczowe: zrównoważony rozwój, ekonomia zrównoważonego rozwoju, środowisko przyrodnicze, usługi środowiska, system, teoria systemów

Introduction

Ecosystem services can be viewed and examined from a biological and ecological perspective as well as from a socio-economic perspective. From a biological standpoint, ecosystem services involve all natural processes that shape the developmental niche of man and provide adequate environmental foundations for human life. In a socio-economic view, ecosystem services are natural processes, strengths and values which are of vital importance for economic processes and for the development of civilization.

In the idea of sustainable development, it is assumed that all advantages and disadvantages should be taken into account in an economic calculation. In the past, when the use of the natural environment had no adverse effect on ecosystem services, it could be left out of the economic analysis. Today, however, ecosystem services must be a subject of economic research. This is due to the fact that the efforts to increase the material well-being of man have led to the deterioration of the environmental foundations of life and to the increasing costs of producing goods and services. To date, scientists have not reached a

consensus on how to understand and classify ecosystem services and what exactly they should include. This issue needs further discussion (Poskrobko, 2011; Michałowski, 2011; Gómez-Baggethum et al., 2010; Costanza, Kubiszewski, 2012).
One of the strategies to develop a coherent and consistent approach to the economic category of ecosystem services in the economy for sustainable development is to adopt a systems perspective in the research. The aim of this article is to present original systemic aspects in the research on ecosystem services in the emerging economy for sustainable development.
In the discussion on the emerging economy for sustainable development, different criteria of values as axiological bases for economic and environmental analyses have been proposed. Within environmental ethics, moderate and extreme anthropocentrism, biocentrism, and holism are usually distinguished (Borys, 2005, 2011; Rogall, 2009; Kośmicki, 2009; Kiełczewski, 2011; Poskrobko, 2012). It should also be noted that axiological foundations of the economy for sustainable development can be viewed in terms of responsibility. In this approach, the need to integrate different types of responsibility (legal, economic, financial, social, and environmental responsibility) has already been emphasised. Moral (ethical) responsibility plays a primary role in this integrated responsibility and it pervades all other kinds of responsibility (Borys, Borys, 2011).
In this study, moderate anthropocentrism, along with the anthropological model of *homo sustinens*, forms an axiological foundation for the analysis of systemic aspects in regards to economic category of the ecosystem services for society and economy in a perspective of the emerging economy for sustainable development.

1. Concept of a system

In the literature there are many definitions of the term *system*. A broad overview of how *system* is understood was given in 1976 by J. Habr and J. Veprek. Representatives of systems sciences suggest the following definitions of the term:

- A system is a set of units with relationships among them – L. von Bertalanffy,
- A system is a set of objects together with relationships between the objects and their attributes – A. Hall,
- A system is a set of interacting elements – W. Ashby,
- A system is an organized number of elements related to each other and carrying out certain functions – S. Beer,
- A system is a set of objects and activities that has four key characteristics: content, structure, communication, and control – P. Rivett and R. Ackoff (Jajuga et al., 1993)

On the basis of the definitions presented here and others which can be found in the literature, some common characteristics of a system can be identified:

- a system is a set of interrelated elements,
- a system is related to its environment,
- a system may be a part of a system of higher order,
- the elements of a system may themselves constitute systems of lower order.

To put it simply, a system can be described as a set of elements and the relationships among them together with the attributes of these elements. Attributes are characteristics of the elements, whereas relationships bind individual elements into a whole. Distinguishing individual elements of a system is necessary in order to compare different systems. Differences in the composition of systems result in quantitative differences, while differences in the relationships among systems' elements lead to qualitative differences.
The basic concept of systems theory includes the ideas of system structure and of the systems environment. The structure of a system can be defined as a set of elements and the relationships among them. The environment of a system, on the other hand, can be described as a set of elements not belonging to the system, but rather attributes of which affect the system and also are affected by the behaviour of the system. Immediate and remote environments are distinguished. Systems have inputs and outputs. The input is a relationship connecting a system with its environment in such a way that the environment affects the system. In contrast, the output of a system is a relationship connecting the system with its environment in such a way that the system affects the environment. Systems are characterized by states that can be expressed in numerical presentations of their attributes. For static systems, a state is expressed by the following vector:
$x = [x_1, x_2, \ldots, x_m]$,
where:
m is the number of attributes that define a system,
x_j is the value of j-th attribute.
In dynamical systems, the state of a system at some moment t is expressed by the following vector:
$x(t) = [x_1(t), x_2(t), \ldots, x_m(t)]$,
where:
$x_j(t)$ is the value of j-th attribute at the moment t.
Static systems have only one state, whereas in a dynamical system there is a trajectory, which is a sequence of the system's states in successive moments. In other words, it is a set of vectors which contain the numeric characteristics of a dynamical system at a certain moment (Jajuga et al., 1993).

2. Properties of dynamical systems

All dynamical systems share some properties that static systems lack. Dynamical systems undergo structural and functional changes over time. Any analysis of a dynamical system should take into account the relationships between the system and its structure, and the relationships between the system and its environment. At the same time, it is important to identify the causes of changes in the environment and in the system as well as the rules that govern the behaviour of a system. The most important properties of dynamical systems include:

- equilibrium – a defined state of the system resulting from the mutual interactions between internal and external forces which neutralise each other, and so they do not cause any changes in the structure of the system; permanent equilibrium in the system is a theoretical concept that serves as a convenient model. It should be remembered, however, that the reality studied is based on the phenomena and processes of dynamic equilibrium; the individual systems' states in the society-economy-environment macro-system are always closer to or further away from the point defined as equilibrium;
- stability – the behaviour of a system returning to equilibrium some time after being perturbed from it; what is necessary, though insufficient is the ability of a system to change the force of interactions among its elements provided that the elements and the directions of interactions stay the same. A system is considered stable if the interactions reduce the effect of perturbations; an example of such interaction is a negative feedback;
- ultra-stability – the ability of a system to return to equilibrium by changing purposes of its individual elements and so changing its internal structure. This property characterises only some systems such as living systems, systems with living elements, or some artificial systems consisting of people and material resources;
- adaptation – the ability of a system to maintain its structure and operate in a changing environment. Two types of adaptation can be distinguished: primary and secondary; primary adaptation occurs when the system secures its durability, and secondary adaptation occurs in the process of system's development. Additionally, there are active adaptations which come from the system itself and passive adaptations which are forced from the outside;
- homeostasis – the ability of a system to maintain a stable, relatively constant condition of properties that determine its existence despite changes in the environment. Homeostasis is focused on reactions against interferences from the environment as well as those generated within the system; these interferences may make the system lose its dynamic equilibrium or disturb a trajectory leading to this equilibrium. Interferences may have adverse or beneficial effects on the system's development. Importantly, due to the system's inertia, between the moment that interferences occur and the system responds to them, some specified time elapses;
- equifinality – characterises only open systems which can achieve some given end state through different intermediate states or, in other words, where the end state is not dependent on the initial one. In closed systems, by contrast, the final state is determined by the initial one;
- transformation (transfer) – the relationship between the input and the output of a system, given by the formula $y = GX$, where G is the capacity of a system to transform the input variable into the output;
- dynamics – the unilateral or reciprocal interactions of specific elements within the system; there are two basic types of dynamics: supply and information;
- synergy – the interaction of elements in a system to produce an effect greater than the sum of their individual effects; the synergy effect is the result of improvement processes, adaptation, activity and development of the system (Jajuga et al., 1993; Habr, Veprek, 1976; Bertalanffy, 1984; Kisielnicki, 1986; Flakiewicz, 2002).

A category that can be distinguished from dynamical systems is that of large dynamical systems. These systems have a significant number of elements that cannot be fully identified. They are particularly complex and hierarchical. The most important properties of large dynamical systems should include:

- consistency – results from interactions among the elements of a system and refers to its functional integrity;
- separation from the environment – each system is in some way separated from the environment, because the interactions within it differ from the external ones in their nature and intensity; thus, there is a boundary which shows resistance in the processes of matter, energy, and information exchange with the environment;
- openness – a system is interconnected with its environment through its inputs and outputs;
- harmony with the environment – large dynamical systems are focused on long-term operation, which involves cooperating with the environment by beneficial exchange of matter, energy, and information;
- high complexity – a large number of elements and interactions among them;

- versatility – large dynamical systems are characterised by a variety of specialised elements, which means that the system as a whole can perform many functions;
- having multiple states – behaviour of a large dynamical system is subject to many internal and external factors, which makes it difficult to predict because it is stochastic and there are many states it can have;
- organization – the interaction of the system's elements according to certain rules in order to fulfil its function; it is a dynamic property, as it is reflected in the functioning of the system;
- purpose-orientation – large dynamical systems are usually organized in such a way that despite disruptions and changing conditions, they maintain certain specific states or attempt to reach them; if these constitute the purposes of a system, we talk about purpose-orientation;
- hierarchy – hierarchical way in which a system is organised;
- ability to grow and develop – refers to increasing the complexity, the number of purposes and/or functions to be performed. This property is associated with learning processes, system improvement, or adapting to changing conditions;
- economy – savings in the use of matter, energy, information, and time. This property is realised through the rational allocation of resources, depending on the importance of various functions;
- information – information about large dynamical systems is necessary for their proper functioning. This information is collected and processed by systems and its extent determines the effectiveness and efficiency of how they operate;
- energy – large dynamical systems perform work that requires appropriate internal energy, which is also replenished from the outside;
- inertia – the property that makes it more difficult to undertake new tasks in conditions of rapid changes in the functioning of a system and its environment. Systems with strong interactions and central control usually have greater inertia than smaller systems with highly autonomous elements. High inertia reduces the efficiency of a system;
- indefiniteness – when studying large dynamical systems, it is impossible to learn about all their elements and relationships among them at any given time in the past and in future;
- uncertainty – is linked to the future of large dynamical systems and it means that it is not possible to determine the exact state of such systems in the future. This state depends on natural (objective) factors and on the ways individuals and institutions act (subjective factors) (Jajuga et al., 1993).

The list of the most important properties of large dynamical systems can be longer. It can be supplemented, for example, with the property of regeneration, destruction, reliability, and innovation. The list presented here includes the most common properties that are particularly relevant for the socio-economic and environmental analysis of ecosystem services.

3. Systems approach in the light of the paradigm of sustainable development

The origins of the systems approach go back to the attempts made by A. J. Lotka to integrate ecological and economic systems. In his book *Elements of Mathematical Biology* published in 1925, he presented inter-disciplinary systems assumptions. His ideas were slowly received, but they had a significant influence on environmentalists (for example, E.P. Odum and H.T. Odum) and economists (for example, P. Samuelson, H. Schulz, H. Simon). A.J. Lotka greatly contributed to the later development of ecological economics by integrating the approach to ecological and economic systems. According to him, ecological and economic systems form a whole limited by the streams of matter, energy, and information, and are subject to non-linear dynamics. Formally, the systems approach in science was initiated by L.von Bertalanffy in 1950. He stated that it was necessary to consider complex systems in all disciplines, which resulted in a fundamental shift in scientific thinking. The mechanical analysis of causal sequences and the fragmentary approach proved to be inadequate in the research done in the natural and social sciences, as well as when solving practical problems of modern civilization. Currently, it is believed that systems theory is a branch of science that deals with the study of any system as a whole in a specific environment. Systems research is carried out in relation to the structure, operation, and development of systems. Systems analysis is one of the areas of systems knowledge, which is a set of methods and analytical techniques used to solve situations that require decision-making. Many social, economic, and environmental problems, including those related to the research on the economic category of ecosystem services, are solved by means of a systemic approach. Various systems methodologies are employed: the method of analysis and identification of systems and phenomena, the method of studying the behaviour of a system, the method of determining the purposes of system's operation, the method of assessing behaviour, or the general comprehensive research method (Kośmicki, 2009; Habr, Veprek, 1976; Kisielnicki, 1986; Steckiewicz, 1991; Rzemykowski, 1994).

The systems approach distinguishes many criteria for the classification of systems. For instance, systems can be grouped according to the number of elements or states they have, how they interact with their environment, how they change over time, or according to the degree in which humans participate in their construction. Systems can also be classified according to several criteria simultaneously. An example of such a classification is the classification based on the following criteria: whether a system is ideal or material, natural or artificial, made of things or people, or whether it operates in an active or passive way. The following systems can be distinguished according to this classification:

- ideal systems – include conceptual systems, i.e. ideas or concepts, for example ethical, moral, or legal systems, language systems;
- physical (real) systems – made of physical elements;
- natural systems – material systems that have been formed by the natural environment, such as a cell, organism, ecosystem, the Earth,
- artificial systems – material systems that have been deliberately created by man,
- systems composed of things only – artificial systems that consist only of elements which are physical, for example a machine or a building,
- systems composed of people only – artificial systems that consist only of people, for example a family, social class, people employed in some company,
- mixed systems – artificial systems that consist of things and people, for example a household, a company, or national economy,
- passive systems – systems which do not have the capacity to make their own arbitrary decisions about how they operate; changes in how they operate occur over time and are usually dependent on natural processes,
- active systems – systems which can make arbitrary decisions with respect to how they operate, for example automata, systems made of people, mixed systems (Flakiewicz, 2002).

The analysis of the Earth system poses a great scientific and practical challenge as it refers to large scale spatial-temporal structures and functional phenomena. The systems approach assumes that the main effects can be explained only by the interaction of a large number of elements. The Earth is viewed as a non-linear system that is characterized by competing dissipative states which occur under the influence of external and internal changes. The development of this system can be gradual or sudden and it may have irreversible effects. Systems analysis of the Earth requires combining various disciplines; the importance of the biosphere as an active component of the Earth system has already been recognised and emphasised. The purpose of the systems analysis is also to determine alternative potential dynamic states of the biosphere and of its components, which cause change. Furthermore, research methods for determining safe states and critical points that disturb these states are searched for (Kośmicki, 2009).

The systems approach in view of the paradigm of sustainable development is oriented towards understanding the scope, range and duration of development processes in the systems of society, economy, and environment. It is assumed there are mechanisms for sustainable development in two areas: inter-system and intra-system. The inter-system area concerns balancing the relationships between the development of the system of society and economy, society and the natural environment, and economy and environment. In reality, there are also indirect relations concerning interactions between society and the environment through the economy, society and economy through the environment, and the economy and environment through society. Maintaining sustainability in the society-economy-environment macro-system does not mean that the individual systems would develop at the same rate. This is a situation which is both unattainable and disadvantageous. Instead, it is necessary to adjust the scope and pace of changes in these systems. The main problem of sustainability is diversifying the developmental cycles of society, economy, and the environment. The environment is developing at a slow pace in the ecosystem and geological time; though, some anthropogenic impacts are visible in the short term. Also, there are very limited possibilities for controlling its development. On the other hand, the economic system is developing rapidly and is much easier to control. Sustainable development does not always mean slowing down the economic processes, as the rapid growth of the latter can limit material and energy consumption, and thus reduce the pressure on the environment. The social system is characterized by a growth rate which is the result of changes in the environment and economy. It is more difficult to control than the economic system. As each system has its own development cycles with characteristic amplitudes, the macro-system does not have to display equilibrium, while it may be on the way to attain it. Thus, assessment of sustainability levels of the macro-system should be carried out over a long period of time, i.e. several decades. The research conducted over a shorter time can only reveal some tendencies in the development of the macro-system's elements. The intra-system sustainability refers to sustainability within the social, economic and environment systems. The ways and methods of achieving this sustainability are extensively described in the social, economic and environmental literature (Poskrobko, 2005).

The processes of sustainable development of systems require an interdisciplinary approach, which is significantly facilitated by the concept of integrated order. This concept can be defined as a positive state of development changes that coherently combines its basic component orders, i.e. social order, economic order and environmental order. The integrated order is a benchmarking mechanism of the macro-system development model characterized by sustainability. It cannot be identified with sustainable development because it is a target state, while sustainable development is a process. The integrated order means consistent creation of social, economic, and environmental orders. In strategic planning, two additional orders are identified: an institutional and political in the social order, and a spatial order in the environmental one. Their integrity is achieved through a balanced protection of social (and human) capital, of anthropogenic (especially cultural and economic) capital and of natural (natural environment) capital. The binding force in the process of order integration is an axiological foundation for the sustainable development paradigm. In an in-depth analysis of the role of integrated order for sustainable development of the macro system, it is necessary to identify similarities and differences in the approaches of various sciences to realisation of sustainable development. These approaches differ significantly depending on the field and discipline (Boris, 2011).

4. Systemic factors in establishing orders of sustainable development

The thermodynamic perspective and the entropic interpretation in particular are becoming increasingly important in systemic development of the integrated order and of its component orders (pillars). The entropy of systems can be identified by many processes or phenomena and it can be viewed in different ways (Czaja, 1997). Firstly, the entropy of a system is its property which involves the creation of growing disorder. Systems can exist and function by taking matter, energy, and information from their environment. According to the law of entropy, isolated systems are characterized by increasing disorganization and disorder. In order to exist longer, they have to draw low entropy from the environment (resources of available and useful matter, energy, and information), and so they become open systems. Lack of resources of low entropy means the state of thermodynamic equilibrium. The presence of these resources is a prerequisite for the evolution of systems and the movement of matter in the space-time. The second aspect of the entropy of systems is the material and energetic dimension of their processes, which cannot be separated from the symbolic dimension. This is very important in the analysis of economic processes, which have both a material dimension and a financial one. All parts of the economy from local to global are, in fact, parts of an open system of communicating vessels. The third aspect of the entropy of systems is connected with producing pollution and waste, which are streams of high entropy. This is a side effect of the systems' operation. In the case of economic processes, it is a by-product of satisfying human needs and of preserving human life and civilization. The fourth aspect of the entropy of systems is the ability of systems to self-organise by making use of the resources of low entropy from their environment. Self-organisation is an expression of the entropy of a system. It requires higher levels of low entropy than the continuance of the system at a lower level of organization. The survival of any system is therefore dependent on the processes slowing down the entropy within this system. The aspects of entropy presented above constitute one way of describing this property. According to the principle of ordering by fluctuation, which attempts to combine entropy laws with the idea of social and biological systems aiming to increase their ordering, the system's dynamics allows it to temporarily move away from the state of maximum entropy (thermodynamic equilibrium) being a result of internal processes of forming more developed organizational structures and dissipative structures. At a new level of organization, the system's entropy is high, but with the increase of adaptation, it shows a decreasing tendency. The use of new resources reduces the overall level of entropy within the system, but their continued use leads to the increase of entropy. Evolution of a system consists in continuous attempts to reduce the level of entropy. This can be represented by the following formula:

$dS = d_eS + d_nS,$

where:

dS means an increase or decrease of the total entropy of a system,

d_eS means an increase of the entropy of a system,

d_nS means negentropy of a system (a measure of the degree of organization, negative entropy).

Evolution of each system can be progressive or regressive. In natural and social sciences, evolution is defined as a transition process from simpler states to more complex ones, from less diverse states to more diverse ones, or from lower states to higher ones. Taking into account both the evolutionary and the thermodynamic perspective, evolution can be understood as the system's developmental processes which lead to the increase in the system organisation (self-organization). Such understanding of the socio-economic development processes has been present in the economic theory. The concept of evolution is most broadly approached in the so called modern evolutionary theory of development. This theory employs the category of evolution of the genotype and the phenotype, category which has been developed in natural sciences. The genotype is a set of all genes of an organism that determine its properties. The phenotype, on the other hand, is the composite of all characteristics of an organism which are influenced both by its genotype and by environmental factors. In contrast to evolution of the phenotype, which can be predicted, evolution of the genotype is unpredictable. This is due to the following three factors: firstly, it is impossible to predict the effect of mutation; secondly, it is impossible to predict the influence of mutation on the genetic material; and finally, the influence of genetic variation on the phenotype is unpredictable. It is much more difficult to identify a set of characteristics pertaining to the economic genotype in economics than in natural sciences. What we can do is to merely attempt to determine a set of elements that can create this genotype. These elements include the preferred rules ordering operation of corporate entities, technology, and social, economic and legal institutions. The biological and the economic phenotypes are dependent on the genotype and the environment of the system, in particular the natural environment. It can be assumed that the phenotype is the state realising itself in a certain opposition to the genotype and the resultant of implementation of possibilities determined both by the genotype and the environment. In economy, the economic phenotype can include the following elements:

- production technology used,
- capital goods and their resources used,
- capital goods, consumer goods and services produced,
- amount of goods and services and their prices,
- distribution of consumption, income and wealth,
- market structure (Czaja, 1997).

In an evolutionary perspective of systemic establishing of individual sustainable development orders, three types of systems can be distinguished: physical, biological, and socio-economic systems. Taking into account three main pillars of sustainable development, it should be noted that in physical systems, evolution is a simple process and it proceeds differently from evolution taking place in biological and socio-economic systems. In the physical genotype, evolution or/and sudden changes do not occur. This stability of the physical genotype makes it possible to focus on the phenotype and search for methods to study and analyse the dynamics of the physical system. In the case of biological systems, the process of evolution is more complicated. In its first phase, there is a simple reproduction which does not bring about any changes. However, when random mutagens appear, they cause some change in the genotype, which therefore results in a modified genotype and the second phase of Darwinian evolution begins. This changed genotype gives rise to a new phenotype which is subjected to natural selection. If the new phenotype is successful, new characteristics are passed on in the new genotype, which will help to create another phenotype. Otherwise, there will be a return to the original genotype. In both cases, the next phase of reproduction will begin. In socio-economic systems, evolution proceeds similarly to evolution in biological systems, but there are some differences. In the economic theory of evolution, the genotype is a set of possibilities; hence, every invention changes the previous genotype irreversibly. In the first phase, *reproduction* of the phenotype created on the basis of the genotype takes place. An invention changes the genotype in the process of introducing innovation of a new phenotype. This new phenotype is subjected to market selection. If it is successful, the new genotype will give rise to a new phenotype, which in the third phase will be reproduced. If it fails, there will be a return to the earlier phenotype, which will be reproduced in the third phase. In the long term, evolution of socio-economic systems will resemble a spiral stretched in time with its subsequent loops connecting in time. When describing systems in terms of evolution, it should be remembered that biological systems and socio-economic systems are different. These differences can be explained by at least three reasons. In the economy, changes which are not successful are retained in the genotype. In addition, changes in the genotype occur as fast as, or even faster, than in the phenotype. What is also important is that in economy the phenotype may affect the genotype, which is not possible in biological systems (Czaja, 1997; Georgescu-Roegen, 1971; Kwaśnicki, 1996, *The Evolutionary…*, 2005).

Additionally, socio-economic systems display certain adaptation properties which are negentropic in nature, such as the property of innovation and self-organization. Negentropy of these systems can be understood as a possibility of reducing physical entropy or slowing down its growth, as well as reducing information entropy by increasing organization of the system. Having this in mind, socio-economic systems can be classified in two ways. The first classification is based on the rate of creating entropy. This rate demonstrates how extensive economic processes implemented in the socio-economic system are. The other classification may be based on the degree of creating negentropy, which expresses the ability of generating processes that enhance survival and development. The differences between natural processes and socio-economic processes are major problems of such classifications. An increase in entropy in the natural environment is automatic, whereas socio-economic processes are conditioned by human activity. They use low entropy in accordance with established rules and regulations. In the natural environment, there are phenomena that balance potentials and organization of biological life; whereas in the economy, organizational activity is a conscious action. As a result, entropy increases faster in economic systems, and additionally, more information is generated and used. It should also be noted that the real purpose of socio-economic processes is not high-entropy, but satisfying needs in an adequate way (Czaja, 1997). These differences must be taken into account when establishing orders of sustainable development, which would preserve the natural environment and its services for the society and economy.

5. Assumptions of systems research on ecosystem services in the economy for sustainable development

In the emerging economy for sustainable development (economic theory of sustainable development), the research on ecosystem services should be carried out in an interdisciplinary macro-system approach (*Ekonomia ...*, 2011; Poskrobko, 2011, 2012). This requires undertaking research aimed at creating a coherent and multi-level sequence of paradigms increasing in their accuracy. The most general paradigm of sustainable development (at the first level) should generate new paradigms in various fields of science (at the second level). On this basis, sets of paradigms of scientific disciplines (at the third level) should be developed, serving as reference points for developing program proposals in the research conducted and education (level four). Developing a logical sequence of paradigms is currently in the early stages, especially when it comes to the second and third level. The first and forth one are more specified. At the first level there is a noticeable interdisciplinary integration of features, principles, objectives and development orders and at the fourth level there are quite comprehensively developed theories (Borys, 2011). So far, however, uniform methodological foundations of the systems research on ecosystem services and a coherent economic theory that would be based on the paradigms of the higher levels have not been developed.
In the author's view, one of the basic assumptions of the systems research on ecosystem services in the economy for sustainable development should be an approach based on the concept of co-evolution, which is widely used in the biological sciences and increasingly in the social sciences. Such an approach attempts to analyse the actual development, and not just seek causal, unilateral relationships. Nowadays, the concept of co-evolution is used in the analysis of ecological interdependencies in view of the specific reasons for the development of the human species (anthropogenesis) and historical stages of development of human culture. Recently, the concept of co-evolution has been applied also in ecological economics. So far, the relationships between humans and their natural environment have been studied in detail by ecological anthropology. This field of study focuses on the historical aspect present especially in economic forms of appropriation, transformation of the environment, and ideological ways to justify adaptation strategies adopted, as well as in forms of interhuman relations and organisation of society. Socio-economic systems across space and time differ in terms of factors influencing their co-evolution with the environment. Ecological economics attempts to provide an in-depth explanation for the co-evolution of economic and ecological systems. What prevented the integration of economics and ecology was a common assumption that the natural environment and economic systems could be considered separately. This view is still held by many economists. Similarly, most naturalists emphasize that the natural environment is independent of society. According to R.B. Norgaard, the relationships between the system of natural environment and social systems and their changes are co-evolutionary. He proposes that social organization should be oriented towards achieving sustainable development and that cultural evolution should be viewed as a process of co-evolution of values, knowledge, organization, technology, and the environment. The co-evolutionary approach does not mean denying the direct impact of society on the environment. It emphasizes, however, the chain of future events and human interference changing selective pressure and thus also the role of ecosystem characteristics. They have a reciprocal effect on the selection of values, knowledge, technology, forms of organization, and subsequent interferences in development of the natural environment. In a co-evolutionary approach, the solution to ecological problems caused by civilisation development is not just about creating the right market incentives or regulations, but rather developing ways to use resources and ecosystem services effectively. After all, modern values, knowledge, and social organization have co-evolved with the environment (Kośmicki, 2009).
The systems research on ecosystem services in the economy for sustainable development should also adopt greater physicalisation of concepts and analyses. An insufficient degree of physicalisation is one of the major problems in modern economics. Considering all the phenomena and relationships in the society-economy-environment macro-system only in financial dimension constitutes an important methodological limitation. This problem of the 20th century economics was emphasised by N. Georgescu-Roegen. The emerging economy for sustainable development in which the environment system is given an in-depth consideration highlights the necessity for physical analyses of matter, energy, and information in four-dimensional space-time (Czaja, 2011).
Including both physical analyses and biological aspects in the systems research on ecosystem services in the economy for sustainable development is possible when we draw on the achievements of H.T. Odum. He initially worked on the flows of matter and energy through ecosystems, but over time he broadened his approach and went beyond the economic and thermodynamic problems as viewed by

N. Georgescu-Roegen. His approach encompassed all the systems, from simple physical systems to complex biological, social, and environmental ones. In his book *Environment, Power and Society*, he examined ways to integrate diverse systems, assuming that the energy flux is the primary integrating factor. The research conducted by H.T. Odum into the flow of energy through systems and their dynamic models inspired many scientific studies. They refer to, for example, the input-output analyses of energy and matter in ecological and economic systems, dynamic simulation models of ecosystems, and integrated economic and ecological systems (Kośmicki, 2009). The systems research on ecosystem services should take into account the distinction made by H.T. Odum between energy efficiency (ratio of useful output to the total input) and services (amount of work done). This distinction is a refinement of Lotka's law of energy as an evolutionary criterion for systems processes' analyses. According to H.T. Odum, low energy efficiency results in zero services since no work is done. At the maximum energy efficiency, the services again become low because the processes of achieving maximum efficiency must be invariable. Here, they are infinitesimally small, and so the value of the work done equals zero. Maximum services are achieved at average energy efficiency at high efficiency it is wasted. It can be concluded that those systems that maximize the services, and not the efficiency, are beneficial. This is true about ecological and economic systems which need low entropy to operate in a sustainable way (Kośmicki, 2009). The study of ecosystem services must also take into account the fact that characteristics of biological life make it possible for ecosystems to generate negentropy in the macro-system of society-economy-environment.

Yet another very important aspect of the systems research on ecosystem services in the economy for sustainable development is the aspect of time (dynamic aspect). When analysing phenomena and economic processes, time can be treated both as the cause of changes and as dimension. In the first case, it is analysed as an aggregated or disaggregated determinant of certain phenomena and economic processes. In an economic model, time significantly affects the analytical form of the model (discrete or continuous functions), and the nature of the variables used (streams and resources). Time variable is sometimes analysed on the basis of a set of natural numbers ($T_1, ..., T_n$) and it refers to, for example, years, months, or days. Then, it assumes discrete values. If the time variable is analysed using real numbers ($t_0, ..., t_n$), then it assumes continuous values. Discrete and continuous time analysis does not require determining how time is viewed, for example whether in logical or real terms. Discrete time is divided into periods of constant length which are treated as its units. When they are combined with some given economic variable (for example, production or revenue), we get a stream which is the ratio of the amount (given in natural or monetary units) flowing through a given surface (space) to time. The economy or market (socio-economic space) can also constitute space. The most typical streams include production, income, consumption, and investment. Each stream has its time dimension, indicating a given amount per unit of time or period (time interval) (Czaja, 2011B). The systems research in the economy for sustainable development should accept the existence of streams of ecosystem services. Three basic types of streams should be identified: material, energetic, and informational. All of them have a spatial character.

Conclusion

One of the major methodology problems in the economy for sustainable development is overcoming gaps in the necessary consilience of knowledge. It is possible to develop a common set of fundamental abstract laws and ways to verify them empirically. Taking into account the fact that the economic and non-economic human activity involves elements which are subject to physical causality, it can be concluded that in the research on ecosystem services in the economy for sustainable development, consilience of knowledge is possible. In fact, the role of ecosystem services in the development of civilization can be fully understood only when we take the model of society-economy-environment macro-system as a starting point.

Currently, consilience of knowledge can be achieved with the use of two basic research strategies: reductionism and complex systems theory (Wilson, 2002). At the current state of knowledge, the first strategy enables only mutual penetration of various aspects of ecosystem services. The second strategy, being a kind of synthesis, allows the realization of consilience of knowledge in the economic theory of ecosystem services. The theory of complex systems is already applied in the research on the beginning of the universe, functioning of cells, neurological foundations of the mind, climate change, and evolution of ecosystems, among others. The systems research on ecosystem services in the economy for sustainable development should search for algorithms that balance economic processes, which would lead to sustainable and lasting civilisation development.

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