

Management of the Natural Environment – A Systemic Approach

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Abstract

Our paper presents natural environment functions in a systemic approach. Its main principle is to consider a problem as a whole and to perceive reality in the same way. This approach is implicated by the crisis of reductionism in explaining natural, social and economical processes and phenomena, as well as by still rising and intensifying consequences of human interference in the environment. The synthesis of ecology rules and the most important features of complex dynamic systems implicate the statement that balance in the environment is a special state rather than a destination state because natural systems undergo continuous evolutionary changes. The existence of feedback makes the changes either run gently and die out or take a catastrophic course and leave the control of societies interfering in the environment. The systemic approach to natural environment functioning presented in this paper suggests taking care in its economical application and forming. In theoretical consideration it has been pointed out how economical societies should shape their relations with the environment so that they become the basis for sustainable development.

Keywords: natural environment, management, functioning, systemic approach

Introduction

Growing scale and the intensifying impact of human intervention on the natural environment mark a definite end to its perception as a pool of utilities, resources, and natural attributes used exclusively to satisfy social and economic needs and economic growth. Such an approach allows us to perceive limits of intervention and permissible changes in the environment essentially as dependant exclusively on current economic and social needs; and societies which manage the environment are too often overoptimistic as to the possibilities of reversing future degradation of the environment. The natural environment, however, is not just a pool of qualities useful to a human managing them.

Predominantly, it is a complex and dynamically changing system that exchanges energy with its surroundings, and is sensitive to changes in the surroundings. Inasmuch as the changes take place within limits of absorptive capacity of the environment, they can be compensated by self-regulating mechanisms. According to Manteuffel [1], they are then not relevant in the economic sense, since - as they do not harm social interests - they do not impact their consumption and production levels. If assimilation barriers are exceeded in exploiting the environment, considered a dynamic system, changes whose implications – not just environmental but also economic in the longer run - may take place which are not only unfavorable but even dangerous to humans. The objective of this article is to consider the dynamics of the environment from the perspective of the systemic approach. The idea is not fully innovative, as the specialist literature more and more often treats the environment as a

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dynamic system. However, presenting the rudiments of the system's theories, and subsequently relating it to the natural environment managed by humans, offers more insight and better understanding of the topic. Ultimately, it hints at the necessity of formulating rules which would define developing appropriate relationships between the environment and humans together with human management action.

The Environment According to Systems Theory – Problem Outline

The word *system* derives from the Greek *systema*, which means 'complex things.' Many definitions of the 'system' can be found as the concept exists in various contexts. Domański [2] claims that the system is a collection of objects together with relationships existing between them and their attributes. The 'system' is also defined as a deliberately orientated whole, a collection of interacting elements [3]. To satisfy the current analysis, a different definition seems to be more appropriate, also suggested by Cempel, who claims that a system is a being that manifests its existence through synergic interactions of its components. Systemic approach accompanies humans more and more in solving issues that represent various areas of engineering and knowledge. Numerous and growing problems on the line between humans and the environment, whose scale is increasingly global, indicate that humans should follow the systemic approach in case of spatial management, as well as management of the environment and its limited resources. The development of societies which manage the natural environment should be viewed in this context – development which is to be permanent.

The key rule of the systems theory is a holistic perception of reality. According to Domański [2], the systemic approach to natural, social, and economic phenomena sprouts from the study of their growing complexity and understanding that research procedures consisting in the separation of individual elements and subjecting them to detailed research have failed and are not sufficient. Currently, the scientific world virtually does not have any doubts as to complexity being an inseparable element of nature. The relationship between humans and the environment should also start to be viewed in the context of the systems theory. Toffler [4] claims that environmental and systemic approaches partly overlap, and that they are similar in the common effort to synthesize and integrate knowledge.

The environment according to the systemic approach is also mentioned in the context of sustainable development, which constitutes the principle postulate in the management of natural resources. Barbier [5] offers that sustainable development includes simultaneous maximization of objectives: biological systems (maintaining genetic diversity, resistance and productivity), economic systems (satisfying basic needs, increasing the number and improving the quality of goods and services), and social systems (retaining cultural diversity, institutional permanence, social justice). According to Constanza [6], we can talk about sus-

tainable development when a relationship between dynamic economic systems as created by humans and dynamic environmental systems ensures: the stability and development of human life, opportunities for growth and self-fulfillment of individuals, and sustaining and developing human culture. According to Constanza [6], the systemic approach to sustainable development guarantees that implications of human actions in the natural environment will remain within specific limits, thanks to which diversity which sustains the life of ecological systems will not be destroyed.

Systems Complexity and Implications – Synergy, Feedback, and Deterministic Chaos

The concept of synergy is an important element of the 'system' definition. From the perspective of systems' dynamics, synergy means regularity, thanks to which a certain problem in its entirety assumes a significantly larger scale from a simple sum of its components. Joint impact of the action has by far outgrown worst-case scenarios in terms of scale, thus confirming a truth known in the systems theory that today's problems are a result of past actions. Therefore, with the current level of knowledge about how natural systems operate, it seems especially important that, while intervening in the natural environment, a human being should try to foresee as early as at the planning stage, and at subsequent investment stages, to take consistent actions to mitigate or prevent the reverse impact of synergy.

Changes in one element may cause changes in many others, and in many cases, in all other elements. This characteristic has serious implications and is also highly significant to the dynamics of the natural environment and how it is being managed. Humans live and act in a complex environmental system, at the same time developing complex and dynamic economic systems. These systems are cohesive, so in order to coexist, they cannot disqualify or destroy one another. Systems created by humans respect cohesion if they grow according to the rule of ecodevelopment.

Systems often use non-linear connections, which lets us observe the phenomenon of negative and positive feedback. The former suppresses and diminishes changes [7, 8], and prevents the system or its elements from losing equilibrium. Toffler [4] claims that examples of negative feedback can be found by scientists as early as in 1950s in almost all aspects of life. In nature, a homeostatic physiological mechanism may serve as an example. It consists of maintaining the continuity of the internal environment by even the most primitive organisms [9]. In the late 1960s, the scientific world came to be interested in positive feedback. It compounds changes and intensifies the rate of processes [8]. Positive feedback destroys stability, and may break up an established order.

Results of non-linear changes are not subject to simple sum formulae in systems. A quantitative increase in the number of components of the social and economic system or an eco-social system usually contributes to upgrading the

quality of the system and the standard of living, as well as actions of its constituents. In a world dominated by humans, concentrated energy frequently reaches and even exceeds its optimal level. It is then that the development of the system reaches its limit: its further quantitative growth contributes to a decrease in the quality and deteriorated dynamics. According to Michnowski [7], the development of the system where, assuming a given macrostructure, an optimal level of energy concentration has been reached, requires fundamental reconstruction of the macrostructure. An alternative solution is the separation of mature links in the system and reaching their self-dependence or a synergic integration with a different system (if former solutions are not possible).

While intervening in the natural environment, mostly it should be kept in mind that as a rule feedback coexists in systems, and it may either diminish or intensify the course of numerous processes. In some cases, an incidental and seemingly insignificant event results in utterly unexpected consequences.

Because of feedback, the environment may encounter deterministic chaos. It is a change process, as well as a set of intensive and dynamic adjustments of the system's components [10]. Any system which behaves in a chaotic way displays certain characteristics. They include self-similarity, self-organization, sensitivity to initial and critical parameters, and the feedback described earlier.

Self-similarity is defined as a tendency for recurring structures at various levels [11]. Coastlines of natural water reservoirs viewed on macro- and micro-scale, as well as deceptively similar tree and leaf structures, may serve as examples.

Self-organization is a result of 'protecting self interests' by each element of the system when competition from other elements is encountered. Chaos potentially contains the new order, and disintegration of a system at the same time acts as an agent freeing consolidating forces. Because of self-organization, the system spontaneously arranges itself around embryos of the newly created structures. The emergence of self-organization means that a system is heading towards an attractor¹. Toffler [4] states that Prigogine, an outstanding theorist of chaos, studied the self-organization phenomenon at an example of raising a termite nest. Inspired by nature, Prigogine ruled that in a strictly determined point where a certain structure organizes itself into a new stage of complexity, it is impossible to foresee which one of many possible structures it will acquire in a moment. This thesis, quite obvious on its own, was accompanied by an important discovery: upon an emergence of a new structure, once the path has already been somehow determined, the system reestablishes its deterministic qualities and order.

Sensitivity to critical parameters is described by, to quote just one, Domański [12], sourcing from the catastrophe theory, which systemizes sudden and non-continuous changes in system states. Paradoxically, such changes result from insignificant changes in one or more parameters. Domański [12] and Michnowski [7] claim that dynamic non-linear systems may encounter non-continuous changes and in such a case, a single parameter value is assigned to two or (bifurcations) or more (multifurcations) values of the dependant variable. Michnowski [7] adds that they describe specific, momentary evolution states of a system with a given macrostructure, after exceeding which, their further growth may happen according to more than one scenario (trajectory.) Because of this quality, after a bifurcation point has been reached, a complex metasystem (the environment, society, and the economy) will follow one of many possible new trajectories while evolving. The trajectories are linked to a new quality of the system. They also determine new living conditions – different from the point of view of their standard, and different in how societies which manage the environment function.

Unfortunately, chaos theory does not offer a straightforward answer as to what parameters apply for the dynamic system to encounter chaos, and when we can expect predictability and order on the other hand. It clearly points to the fact, however, that intervention in a system may lead to chaos. This specifically relates to modifications in the natural world. According to the theory, certain processes initiated by humans may suddenly get out of hand and move toward attractors beyond our imagination. As an example, this may be the case with the creation of a new and utterly different climate worldwide which displays new features and climate zones.

Natural Systems – Life Cycles and Structural and Dynamic Properties

One of the more important generalizations of the systems theory is the cyclical reemergence of systems. It applies to both animated as well as non-animated systems. Natural systems come to life, function within a specific timeframe, and afterwards their activity gradually phases off and they die out.

The life of a system and duration of its particular stages, i.e. formation, relative activity, and gradual dying out) strictly correspond to its type. Cempel [3] states that the following hypothesis can be tried (assuming a high degree of simplification): the higher the level of self-organization of the system, the shorter its life span. It is also characteristic that the more complex the system, the more distinctive and more dynamic are its two life stages: the initial and the final one (which frequently is terminated suddenly). Life in natural open systems, namely capable of exchanging mass, energy, and information with the surroundings, follows through these three subsequent stages:

1. Separation from the environment (the surroundings).
2. Effective cooperation with the surroundings.
3. Gradual loss of effectiveness and return to the environment.

¹ According to the general systems theory, attractor is defined as an area or a point in a certain space of states where a system is heading and around which it remains for a discretionary time period. <http://atraktor.ask33.net>

These stages make up a full cycle: the environment – the environment.

In nature, we can distinguish a number of levels for a system's existence [3]. Starting from the non-animated world, systems which are static structures dominating in geography and anatomy of the universe can be distinguished. The most primitive systems where life structures start to manifest are single cells and bacteria. As the complexity increases, we can distinguish the plant world with plants containing tissue and characterized by genetic and social structure. According to Cempel [3], it is a world whose main feature is growth and self-recreation. In the world of animals with organs or full sets of organs, new properties emerge: awareness, mobility, deliberate effort, and drives. In the human world, on the other hand, self-awareness and the ability to create and interpret symbols emerge. While studying increasingly complex levels of organization in the living matter further, we can move to the overorganism level and distinguish populations and their subsets (biocoenoses). This general classification closes with mature ecosystems, i.e. functional systems of the biosphere where continuous exchange of energy and matter takes place between biocoenoses (the animated world) and biotope (the non-animated world).

In the above context, an observation by Cempel [3] concerning the relationship between the system and its surroundings is important while managing the environment. Cempel claims that the higher a given system ranks in the hierarchy of complexity, the more upsetting or restricting its relationship with the surroundings, and even isolating it lessens its chances of survival. This rule is confirmed even by a peculiar exception, i.e. the closed artificial ecological Biosphere 2 system in a laboratory in Arizona. The fiasco of this expensive experiment with a closed biosphere conducted on a microscale reaffirms that even with the current high technical standards and knowledge levels, sustaining living artificial and isolated ecosystems may prove extremely difficult and doomed to failure without constant human effort (and even with its presence)².

Exchange with the environment is also of high significance to the stability of natural systems in existence. Closed systems (even if initially not static) strive for balance. Thanks to an exchange of mass, energy and formation, open systems may be stable, but the stability – according to chaos theory – in some cases acquires a new quality thanks to chaotic change processes and intensive and dynamic adaptations of the system's components. The openness of animated systems may also be considered a life-conditioning factor. It must be added, though, that closed natural systems practically do not exist. Natural systems become closed or have restricted capacity for exchange with the surroundings as a result of external intervention. Striving for the stability of an animated but closed system equals its gradual dying out.

Taking into consideration various properties that point to structural properties of systems, we can distinguish the entire range of their categories (Table 1).

Table 1. Selected structural properties of systems.

Differentiators	Structures of Systems in the Environment	
1. Formation method	natural	artificial
2. Relationship with surroundings	open	closed
3. Component domination	nonanimated	animated
4. Definition state	deterministic	stochastic
5. Complexity of structures, including:		
a) Type of links	homogenous	heterogenous
b) Number of links	small	large
c) Type of elements	homogenous	heterogenous
d) Number of elements	small	large
6. Function character	linear	non-linear
7. Changeability in time, including:		
a) Function changeability	invariable	changeable, adaptable
b) Structure changeability	fixed	flexible self-organizing
8. Resistance to disruption	unstable	stable
9. Purposefulness	nonanimated	animated

Source: Author's study based on Systems Theory and Engineering [3].

In the context of intervention in natural systems, it is worthwhile noting properties that perform highly significant functions in animated systems at cellular, organism, and overorganism levels. They are: capacity to change function (adaptation) and structure (self-organization), displayed in Table 1. As a response to external stimuli, animated systems may regulate their internal functions and processes by adapting to the environment. Adaptation consists in negative feedback, which is intrinsic to the components of the system and regulation as well as counteract external negative changes. In response to external stimuli, a system may also modify its structures through self-organization. New structures, modified functions and processes allow us to cope with new requirements that are imposed by the environment.

The changing environment is a continuous challenge to natural systems, leading to continuous optimization of actions, and adapting structures and responses. This is the only way for them to retain their identity and life. It is reaffirmed by the 'Red Queen' hypothesis, popular in environmental science, according to which survival is almost conditioned by the necessity of 'constant run'- constant evolutionary changes [9].

² <http://www.cyber.com.pl/archiwum/12/19.shtml>

Developing Humans – The Environment Relationship – Systemic Approach

Domański [13] has studied the development of appropriate relationships in the system between humans and the environment based on dissipation structures³. The author states that such structures dissipate energy and matter collected from the environment.

A developing economy causes the dissipation of energy and matter, which constitutes natural resources. Social and economic activity disrupts the natural environment almost in all cases and causes its increased entropy. As a result, new dissipative structures emerge. They come to being in a state of non-equilibrium, i.e. when the environment undergoes degradation to an extent where an economic initiative arises to collect funds for environmental protection. According to Domański [12], a simple relationship between the economy and the environment cannot fully reflect complex interdependencies between society and nature. Society, marked by intelligence and knowledge, needs to be introduced in the dissipative system. It acts as a regulator and participates in mutual relationships in the system: between the economy, the society, and the environment. It is then that the system not only processes and consumes its resources, it also uses knowledge and informational resources to manage them in an intelligent way and to regulate the scope of exploiting the environment as well as allocating economic resources for its recreation. Such regulation is essential as the system contains limiting factors⁴ that are both environmental and economic in character. Beside disruption of the environment by the economy, there are also reverse processes, intelligent geographical systems also encounter reverse processes, i.e. disruption of the economy to the benefit of improved environmental conditions. Intensifying exploitation of natural resources and burdening the natural environment may cause an emergency state in the system or bring it close to ecological disaster. When a system approaches a state where caution is required, societies exchange the roles of the economy and the environment. The environment becomes the central system, whereas economic resources (with the economy taking over the caring role) are directed toward the environment to order, recreate, and decrease its entropy. Such actions in a complex and cohesive system, however, must have implications on other elements of the system. Increased disruption and entropy of the economy and its structures will follow. A prolonged dissipation of economic resources will cause the system to approach a state where a limiting factor touches the economy. In order for the system to continue, the dissipation of the economy must end where the next interchangeable relationship takes place. If a system is to function properly, it would be best to avoid such shifts and fluctuations. It is, however, virtually impossible because steering the economy is imperfect and environmental pressure

exists. Both natural as well as economic processes are marked by considerable inertia, and feedback writes the non-linear character into their mutual relationship. Societies using their knowledge may and indeed should strive to maintain proper relationships between the economy and the environment. Once the balance is upset, however, and the entropy of the environment grows too high, societies face two scenarios. According to Domański [13], they are as follows:

- Undertake scientific research, as well as implement new technologies and costly investment in order to maintain the current level of resource utilization, while diminishing troublesome implications of environmental destruction.
- Conduct a pro-environmental change in the value system, which necessitates the decrease of environmental burden, restricts economic needs and matches them with environmental capacity.

In reality phenomena of shifting social and economic growth from regions with a damaged environment and high entropy to regions with ordered structure and a better maintained environment take place. Such processes may be accompanied by interchangeability in question; regions freed from the burden will recreate its environment in due course and become more attractive to others that are currently exploited.

A balanced, harmonized growth of the dissipative system between the economy, society, and the environment is not possible without a coordinated environmental policy and rational management of the environment [13]. Hence, societies should conduct research aimed at defining the scope of permissible fluctuations of the environment around the state of a dynamic equilibrium which does not harm its adaptation abilities for self-regulation. It is also especially important to define the level of economic outlays that can restore the environmental standard to a socially required level while not harming sustainable economic growth. An equally important but difficult issue is the determination of interchangeable relationships between the economy and the environment.

A perspective concerning the relationship between humans and the environment according to Bajerowski's concept [14] may also be interpreted as the systemic approach. Bajerowski presents the study of behavioral patterns in a dynamic system consisting of environmental and economic values in a phase space with two degrees of freedom. Assuming that the system in question is cyclically stable, its evolution may be deceptively similar to attaining the state of equilibrium according to Volterra growth cycles, popular in environmental science, in a dynamic relationship between predator and victim. If accumulated environmental values were entirely renewable, the graph of the discussed interdependency could show the predator-victim cycles, whereby economic values which consume environmental values would assume the role of the predator. Based on the above, Bajerowski [14] states that a space of an ideal balanced growth can be clearly defined as restricted area of common growth for both environmental and economic values. Such growth does not favor a given value but

³ *dissipatio* (Latin) – *dissipation*.

⁴ Factor which approaches the tolerance limit for biological organisms (e.g. contents of oxygen in water) or social and economic tolerance (e.g. street throughput).

maximizes both simultaneously. The research by Bajerowski indicates that the method to record higher economic results without losing the prospect of attaining higher environmental results consists in a proper deformation of the depiction described – the cycle of the predator (economic values) and the victim (environmental values). Such deformation should be the target of balanced growth and is completed by, among other things, more effective utilization of limited environmental resources, more efficient management, and implementation of innovations to improve the effectiveness of production factors.

Summary

The development of social and economic systems virtually always takes place at the expense of a different part of this complex metasystem, namely the environment. It is because it is intrinsically linked to the dissipation of energy and matter resources generated in the environment. Dynamic economic growth leads to excessive increase in the entropy of the environment, which - despite the phenomena of interchangeable relationships - until the present has definitely more often acted as the victim in the system than developing economies. Bajerowski's studies [14] indicate, however, that development scenarios are possible where (only if societies do not focus on maximizing economic benefits exclusively – which is unfavorable in the long run) satisfactory growth of both environmental as well as economic values can be realized to a certain extent. Holistic concepts of shaping relationships in the system between humans and the environment are cohesive in many respects. They express the principally formulated need for matching changes in the environment which are brought about by humans with an overriding goal to earn profits, to the requirements and needs existing in that environment. As a rule, violation of the requirements has severe economic implications in the longer run. The systemic approach to the relationship between the human being and the environment allows us to conclude that in order to live and strive in a balanced manner in self-created artificial systems, the contemporary human being will have to depend, to an increasingly

larger extent, on the requirement to deliberately shape, regularly monitor, and correct its relationships with the broadly interpreted natural environment.

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