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EDITORIAL

Sustainable Development Integrated in the Concept of Resilence

Zrównoważony rozwój a koncepcja resilencji

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Abstract

The purpose of sustainable development is to minimize the likelihood of dynamic natural and/or man-made systems to exceed tipping points, when exposed to disturbances. In effect, the systems are protected from losing identity and integrity. The authors of this paper suggest accepting resilience thinking as a basis of setting sustainability goals and reaching the respective targets. The resilience theory provides the method needed to maintain identity and integrity, and to manage system´s dynamics. Of concern are three interwoven systems: environment, society and economy, forming a complex super-system coined *eco-social triad*. Sustainable development of the triad applies to each of the three sub-systems despite conflicting interests of the various actors within each.
Resilience is expressed by the ability of natural or man-made systems to respond dynamically to changes of ambient conditions with the aim to retain their inherent function, structure and feedbacks. To manage such changes and associated disturbances a repetitive sequence of processes (also called *adaptive cycle*) needs to be executed. In ecosystems these cycles are self-regulated and characterized by recycling of materials and energy. In systems dominated by humans adaptive cycles are characterized by phases such as re-evaluation, re-orientation and re-commencement. The concept of adaptive cycles and adaptive management embedded in the resilience theory is considered a promising method to satisfy sustainability goals and reach respective targets.

Key words: sustainable development, resilence, adaptive cycle, economy, society, ecosystems

Streszczenie

Celem zrównoważonego rozwoju jest zminimalizowanie prawdopodobieństwa przekroczenia punktów krytycznych dynamicznych systemów naturalnych i/lub sztucznych (co może się zdarzyć, gdy systemy te są narażone na zakłócenia). W rezultacie uzyskują one ochronę przed utratą tożsamości i integralności. Autorzy niniejszego artykułu sugerują przyjęcie podejścia zgodnego z koncepcją resilencji podczas wyznaczania celów prowadzących ku zrównoważoności. Teoria resilencji odnosi się do umiejętności, dzięki któremu systemy utrzymują tożsamość i

integralność, a także prawidłowo zarządzają własną dynamiką. W obszarze zainteresowania znajdują się trzy przeplatające się systemy: środowisko, społeczeństwo i ekonomia, tworzące złożony super-system określany jako *eko-społeczna triada*. Zrównoważony rozwój triady dotyczy każdego z trzech podsystemów, pomimo sprzecznych interesów różnych podmiotów działających w ramach każdego z nich.
Resilencja wyraża się w zdolności systemów naturalnych do dynamicznego reagowania na zmiany warunków w ich otoczeniu, w celu zachowania funkcjonalności, struktury i zapewnienia właściwego sprzężenia zwrotnego. Aby zarządzać takimi zmianami i związanymi z nimi zaburzeniami wymagana jest powtarzalna sekwencja działań (zwana także *cyklem adaptacyjnym*). W ekosystemach takie cykle charakteryzuje samoregulacja oraz recykling materiałów i energii. W systemach zdominowanych przez ludzkie cykle adaptacyjne występują fazy ponownej oceny, reorientacji i ponownego rozpoczęcia. Idea cyklów adaptacyjnych i adaptacyjnego zarządzania zawarte w teorii resilencji można uznać za obiecującą metodę prowadząca do zapewnienia celów zgodnych ze zrównoważonym rozwojem.

Słowa kluczowe: rozwój zrównoważony, resilencja, cykl adaptacyjny, ekonomia, społeczeństwo, ekosystemy

Introduction

Discussion about sustainable development should begin with a debate about ecosystems and their functions which are considered the basis of the evolution and persistence of life on Earth. In particular, ecosystem functions provide the essential conditions for humans to exist and strive. The difficulty with this approach is the high complexity and the different scales of ecosystems, both in time and space. Although scientific research in ecology has made significant progress, our current knowledge is far from being complete (Hooper et al., 2005). Nevertheless, a series of traits widely accepted by the scientific community are characteristics for natural ecosystems as well as for social systems. Such traits include recycling of energy and matter, self-regulation, adaptability, transformability, stability and resilience (Folke et al., 2010).
Stability and resilience theories have been studied for many years already, based on physics, engineering and mathematics and have been applied in ecological modeling (e.g. Justus, 2008). It is widely accepted that ecological resilience and stability are tightly linked together. Considering alternative stable states of ecosystems (Scheffer et al., 2001) resilience is defined as *the ability of a system to absorb disturbances and still retain its basic function and structure*. As explained by Walker and Salt (2006) a system remains resilient as long as it is able to continuously adjust to the changing ambient conditions, so that the overall system functionality and integrity is preserved (Dawson et al., 1994). This is in accordance with the theory that natural ecosystems are usually in a quasi-stable equilibrium (homeostasis), an assumption that competes with the chaos or catastrophe/disturbance theory.
As humans are part of ecosystems, these concepts have been extended to social-ecological systems (SES) combining ecosystem function with functions of human society (Walker et al., 2004). In this respect we have to consider the dominance and ambivalent character of *Homo sapiens*, his obsession for greed and power (Gigantès, 2012), which counteracts social care and environmental protection.

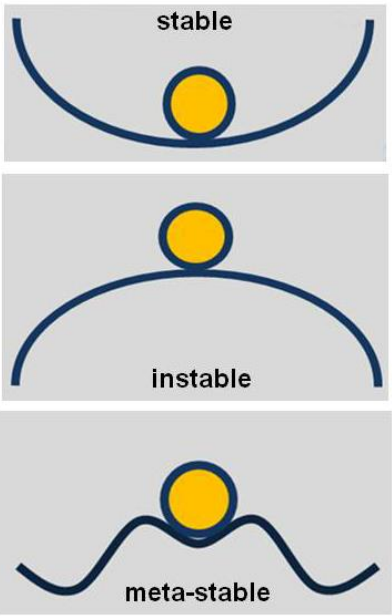

Figure 1. Scheme of the three states of (eco-) systems: stability, meta-stability, and instability. In terms of equilibrium, this translates into quasi-stable equilibrium, labile equilibrium, and semi-labile equilibrium. Meta-stable and instable systems are subject to major shifts or collapse under strong disturbance. Adopted from von Hauff (2014, p. 26).

A system loses its identity and integrity when exceeding a tipping point and being transferred from the state of stability or meta-stability to instability (Figure 1). In case of significant or abrupt environmental changes, also described as *shock*, ecosystems can shift from one state or mode to another. Such shocks might be caused either by natural stochastic events or induced intentionally or unintentionally through human activities (Biggs et al., 2009). As the functional thresholds are exceeded, ecosystems are transferred to a world controlled by a different regime. Such a transfer might be interpreted as collapse. In this context, scaling matters. From historical records we know that despite collapse of ecosystems life persisted under the *new* regime. However, if human activity will lead to the collapse of the global ecosystem persistence of life is more than

doubtful. When considering the Gaia-ecosystem *Earth* (Lovelock, 1988), we should not forget that our planet can hardly be replaced by another one.
In ecosystems, adjustment to changing ambient conditions is driven mainly by self-regulation processes (Odum and Barrett, 2004). Most likely, those processes were responsible for the development of life on Earth over the past billions of years (Lovelock, 1988; Gorshkov et al., 2000). Assuming the correctness of this hypothesis, humankind is well advised to avoid interference with or destruction of natural self-regulation processes. This applies particularly to very large ecosystems such as the oceans, tropical and boreal forests, and very vulnerable ecosystems such as the alpine, Arctic and Antarctic regions. In natural ecosystems, population dynamics is balanced by birth and death rates, amongst other environmental factors. Exponential growth for ever is not possible but self-regulated in nature. Hence, increasing human population, the subsequent growth of quantitative and qualitative demands, and the contemporary paradigm of economic growth become a severe threat of ecosystems if they are not protected.

Social-Ecological Systems (SES) and the concept of sustainability

The expression *sustainable development* (*in German: nachhaltige Entwicklung*) emerged in the 18th century´s forestry industry. To keep wood available for ship building, construction of houses, reinforcement of mining shafts and the production of charcoal for smelting metals, Hans Carl von Carlowitz (1713) suggested adjusting the cutting rate to the growth rate of trees. The intention was entirely oriented towards the preservation of economic stability. However, this measure reflects unintentionally a fundamental ecological principle and a human characteristic: the limits of growth and overexploitation of resources, respectively.
In 1818 the Swiss forester, Karl Albrecht Kasthofer translated the German term *nachhaltige Entwicklung* in the French language as: *produit soutenu et égal d´une forêt (timber shall remain a consistent product of forests).* The English translation of *soutenu* (lt.: *sustenare*) is *sustain*. Until deep into the 20th century the ability to sustain the function of forests to deliver wood remained a major concern of forestry.
After the industrial revolution and the economic boom during the second half of the past century the term *sustainability* gained a new dimension and came into political focus. In the 1980s, the Brundtland Commission started working on an agenda for developing long-term environmental strategies and international cooperation. In the report of this commission entitled *Our Common Future* (1987) sustainable development was defined inter *alia as* an obligation to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987). The focus of the report was on intergenerational ecological justice with respect to the natural resources that humans use for their existence and welfare. Meeting such goals will require an integral change in the use of natural resources and in the performance of investments, technology and institutions. In the aftermath of the Brundtland report, the concept of sustainability was expanded. While integrating ecological systems and social systems into socio-ecological systems (SES) (Walker et al., 2004) harmony between people and nature, and human well-being became of general interest. Earlier, Meadows et al. (1972) had suggested that the Earth needs to be considered a limited resource of not only wood but also fossil fuels amongst others. It was generally recognized that overexploitation of such resources and pollution bear the risk of violating the right of future generations to live a decent life. This concept of sustainable development neglects largely the ecological functions of nature. Moreover, the term sustainability not only underwent an inflation of more than 200 definitions, but also greatly lacked implementation (Jucker, 2002).
Meanwhile, our world has entered a new geologic era commonly called the *Anthropocene* (Crutzen, 2002). The anthropocentric world view of the Earth system has been challenged by James Lovelock (1979) and others (e.g. Gorshkov et al., 2000). Lovelock noted that on Earth – in contrast to Mars – relatively constant conditions persisted enabling life (temperature, composition of gaseous substance in the atmosphere etc.). According to Lovelock, this phenomenon can only be explained by the influence of life itself. He concluded that physical, chemical and biological interrelationships form a single self-regulating organism, which he coined *Gaia*. According to the Gaia theory, living organisms shape, but simultaneously also adapt to changes of their environment. In this context Makarieva et al. (2013) speak of *biotic regulation* meaning the capacity of ecosystems to regulate the surface temperature and the water cycle on Earth. Considering the fundamental significance of ecosystems for the life conditions on Earth it appears extremely important to strengthen ecosystem functions in the agenda of sustainable development.

The new dimension: Economy, an equal part of the Eco-Social Triad

The economy is an integral part of the human social system. The technical revolution transformed the mostly rural societies into a producing and trading, i.e. an industrial society, which later changed to a service society and further turned into a consumer society. Economic development gained importance. In the 1990s, as a follow-up to significant large-scale political changes extensive globalization occurred in response to the new political trend of neo-liberalism

and neo-colonization (von Hauff, 2014). Even environmental NGOs, such as the WWF, realized a paradigm change in creating links with the so-called *green economy* (Huismann, 2012).

In 1992, the *Agenda 21* was adopted by 178 Governments at the Conference on Environment and Development (UNCED) held in Rio de Janeiro (United Nations 1992). It differentiates between the Earth providing the basic life supporting function, and the interests of the human society and its economy. Recognizing the economy having evolved into a powerful entity of its own (von Hauff, 2014) becoming a significant driver of global overexploitation and ecosystem deterioration the *Agenda 21* calls for counteraction. It is an action plan with regard to sustainable development of the human civilization in harmony with nature. Hence, another frequently used definition of sustainability emerged: the balance of the social-ecological system (SES) also called socio-ecological triad (Adams, 2006).

The tight entanglement of the three systems (ecology, economy, society) can be visualized by the Venn diagram (Venn, 1881) showing the logical interrelation of the three sub-systems (Figure 2). The eco-social triad with the three interwoven circles is to be understood as a paradox of *unity through distinction* (Katz cited in Grambow, 2013, p. 61). To the outside world the three sub-systems represent themselves as a unity but internally they must keep their identity and act as individual but interdependent systems to remain resilient. Maintenance of balance in the eco-social triad requires that the three components have the same weight. However, the recently emerged power of globalized economy has offset the balance. Good reasons exist for reducing and limiting economic power within the triad. Safeguarding ecosystem function should be given an equivalent importance to the function of economies and societies (Griggs et al., 2013).

Considering the present primacy of humans and their economy, it is not surprising that the relationship between the sub-systems of the eco-social triad is full of conflicts. Psychological studies suggest that a proper understanding of the relationships governing the triad´s sub-systems can lead to effective conflict resolution (Bühl, 1972). Among the required tools of conflict resolution are empathy (understanding motivation and limits of the others), introspection (realizing own motivations and limits), tolerance (allow alternative actions and reaction happen) and monitoring (gain feedback from taking a neutral position for observation of the three-angular processes and effects in action).

This concept is considered to be applicable for conflict management within the limits of the eco-social triad, provided eco-systems are given a voice. Science based intergovernmental institutions and environmental NGOs could take the role of advocates of nature. Understanding ecosystem processes and function, as well as flexible, multilevel and cross-cutting networks within the triad are a prerequisite for adaptive governance of SESs (Folke et al., 2005).

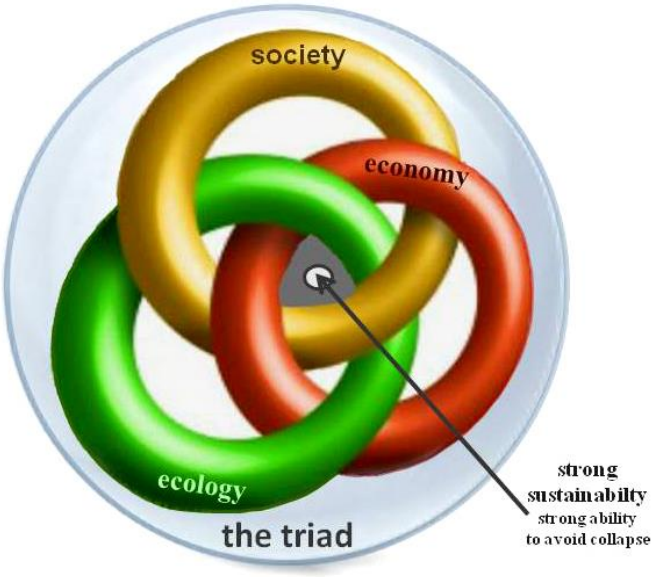

Figure 2. 3D modified 2D Venn diagram (Venn, 1881) representing the eco-social triad and its sub-systems. The grey area represents strong sustainability as all three entities are covered and considered.

Sustainable development based on resilience: Bridging the gap between theory and practice

The current *Millennium Development Goals* (MDGs) set by the United Nations, the respective targets, indicators and metrics have mostly failed to match the need for resilience of SESs. For example, the ecological footprint (Wackernagel, 1994) of developed countries is still far too big and exceeds the carrying capacity of the Earth. Resource exploitation has intensified despite introduction of recycling strategies and new technologies during the last three decades, thus threatening the ecosystem's resilience. The discrepancy between the rich and the poor is constantly increasing, and wars, violence, mismanagement and corrupt regimes counteract truly sustainability and equity, thus threatening societal resilience. And the financial crisis in 2008 revealed that the globalized economy is far from being a resilient system. The development goals and targets expressed in political documents turned out to be rather fuzzy and no more than generalized statements that are mostly not implemented in real policy. However, in a more optimistic view, such statements of high level policy may have a signaling effect (Galaz, 2014).

In SESs, the ability to remain resilient is expressed by continuous repletion of phases such as growth, consolidation, re-evaluation, re-orientation, and recommencement, summarized as *adaptive cycle* (Figure 3). This concept is based on the self-regulated processes of recycling energy and matter in natural

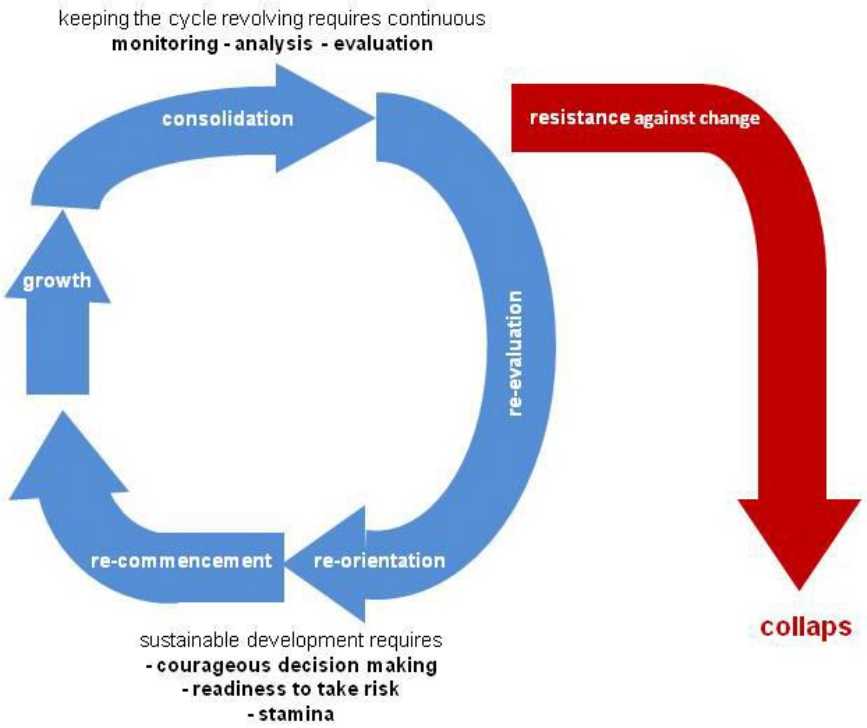

Figure 3. Graphical representation of one of the adaptive cycles within a panarchic system, adopted from Walker and Salt (2006). The blue cycle shows the human-regulated process in anthropogenic systems in response to changing political, economic or societal conditions. It corresponds to the self-regulated recycling of energy and matter in natural systems, where populations feature a growth phase, followed by climax and release. If humans conceptually are inflexible and resistant to adapt for environmental, social or economic changes, then the adaptive cycle is disrupted and the system is likely to collapse (red arrow).

ecosystems. In systems dominated by humans adaptive cycles are to be regulated and controlled on the basis of knowledge, experience and responsibility (Pisano, 2012). Adaptive cycles operate over many different scales of time and space. The manner in which they are linked across scales is crucially important for the dynamics of the triad as a whole (Walker and Salt, 2006; Gunderson and Holling, 2002; Holling, 2004)

In human systems, the adaptive cycle is driven by changes of economic and political conditions, enhancement of scientific knowledge and progress of technical and societal innovation, for instance. Adaptive management leads to long-term success of enterprises. For example, growth and total revenue of an enterprise is limited by conservation of business patterns. In case of threatening inconvenience the undesirable failure is substituted by an innovative strategy to adjust (Figure 3). Neglecting a proper risk assessment and the need to adapt might end in collapse (see red arrow in Figure 3). The case studies presented by Olsson et al. (2006) demonstrate the importance of leadership for successful transformation of SESs towards adaptive governance. Decentralized systems are usually more resilient and flexible than centralized or globalized systems; however, in reality, we have to balance the two. Careful management of adaptive cycles appears to be a promising method of keeping societal and economic systems resilient.

The global threats initiated by humankind (e.g., disturbance and even loss of ecosystem function, inability to satisfy the demand of human society and economy for raw materials, energy, drinkable water, safe food, durable shelter; education; job availability; pollution control) are fundamentally cross-disciplinary and will require respective studies in systems science. In socio-technical systems, information and communication technology are being applied to societal infrastructures (e.g., smart grids, smart cities) to manage the complexity of human civilization (Mainzer, 2013). New integrative research and teaching centers should be established to train students in interdisciplinary networking and to cooperate in interdisciplinary/transdisciplinary teams. Such teams, committed to solve environmental problems, are also demanded in industry, economy, and governmental institutions. In this respect, predictive modeling is a powerful tool to elucidate sustainable development scenarios; however, uncertainties and surprises need to be taken into account.

The intense interconnectedness of all spheres and countries on this planet makes it essential to consider environmental aspects as a major factor for development processes in the 21st century. No sub-system can stand alone and independent of the other sub-

systems of the triad. This enhances enormously the possible effects of a small shift in one of the sub-systems on the other sub-systems. The future Post-2015 Development Agenda based on Sustainable Development Goals (SDGs) and targets will improve the old MDGs in scope, provided they respect the complexity of dynamic systems, thus drawing on the resilience concept (Bloesch et al., 2015). They are to be focused on the mitigation of the anticipated environmental effects which have a big impact on social and economic systems as well. They should foster the reconnection of people to the biosphere and build a new responsible stewardship for our planet (Folke et al., 2011).

In the context of theory and practice, the triad concept is not free of inconsistency. It is an anthropocentric model, as the one fundamental natural system is accompanied by two human systems. There is also a paradox in individual and community human behavior itself, e.g. between the good and the evil, modesty and vanity, the rational and emotions. This reflects the inherent duality or bipolarity of nature (Haber 2013). The duality of humans makes tradeoffs between conflicting interests, objectives or goals difficult as these depend on the negotiation of good compromises. However, this top-down approach contradicts bottom-up participation of local stakeholders which constitutes the basis for sustainable development. As Galaz (2014) points out, both approaches should be balanced and complementing. Since the overlapping area of the three sub-systems is rather small (Figure 2), there is not much margin for truly sustainable solutions that treat the three subsystems equally. This small common area reflects the reality of conflicting interests between developing and industrialized countries, and countries in transition. However, there are always possibilities to balance the conflicting sub-systems and to design policies that strengthen resilience on all three entities. Even suboptimal solutions in each one of the sub-systems can have a beneficial overall effect on the triad and, hence, set the right vector to approach the state of sustainability.

Summary and conclusions

Sustainable development is a process, which can be positively influenced by sound management and responsible governance. With respect to the basic concept of the resilience theory, the readiness to respond proactively to changes is an important pre-condition of maintaining system´s resilience and of supporting the process of sustainable development. In this context the concept of adaptive cycles provides a guideline to a constructive response to changes of environmental, economic and/or political conditions. It requires the willingness of all relevant actors within the eco-social triad to recognize at the earliest point in time such changing conditions and draw respective decisions based on scientific knowledge, experience and wisdom. It is necessary to take risks associated with the departure from accustomed practices, re-orientation and recommencement. In summary, we consider the resilience theory a promising basis for making progress in sustainable development.

It is advisable to consider strengthening the resilience and supporting sustainable development of the three sub-systems of the eco-social triad, the ecology, the society and the economy equally important. Based on such considerations some authors of this paper engaged themselves in a project on Sustainable Development Goals as part of the UN Post-2015 Development Agenda presented in part 2 of this paper (Bloesch et al., 2015). Research and innovation in thinking, understanding and acting support the accurate tradeoffs between the three sub-systems. Moreover, sustainable development of the triad requires simultaneous balancing of each of the three sub-systems despite of conflicting interests of the various actors in each sub-system. Conflict management is an important task, and with reference to psychological studies the application of characteristic traits such as introspection, empathy and tolerance are important in the process of sustainable development.

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