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Stability of the natural environment as a subject of geoecological research

Stabilność środowiska przyrodniczego jako przedmiot badań geoekologii

Abstrakt: Stabilność środowiska przyrodniczego zdefiniować można jako „stopień jego trwałości w warunkach niezmiennego otoczenia i zdolność powrotu do stanu zbliżonego do poprzedniego po zakończeniu oddziaływania zewnętrznych czynników zakłóceniowych" (Richling, Solon 1998, zmienione). Badania stabilności środowiska bazują na teorii systemów, zakładającej, że środowisko określonego obszaru można traktować jako geosystem lub zespół geosystemów. Traktując środowisko przyrodnicze jako geosystem warto zwrócić uwagę, że nie jest to system w pełni identyczny w stosunku do systemów opisywanych językiem matematycznym. Przyroda, środowisko, krajobraz – to „byty" dynamiczne, stale podlegające różnego rodzaju zmianom. Stabilność geosystemów jest zatem stabilnością dynamiczną – geosystemy stabilne ulegają ewolucyjnym zmianom, ale cechują się ustalonym rodzajem funkcjonowania (Widacki 1979b). A zatem nie istnieje – nawet w warunkach niezmiennego otoczenia – pełna trwałość przyrody czy krajobrazu; wraz bowiem z upływem czasu środowisko podlega różnego rodzaju zmianom. Tym bardziej nie można mówić o pełnym powrocie do stanu oryginalnego po zakończeniu oddziaływania czynników zakłócających. Zewnętrzne oddziaływanie na geosystem można określić jako bodziec; bodźce mogą wywoływać (ale wcale nie muszą) w geosystemie określone skutki. Konkretne efekty tych oddziaływań to zakłócenia. Bodźców nie należy utożsamiać z zakłóceniami choćby z tej przyczyny, że często geosystem nie ulega bodźcom („odrzuca" bodziec), a zatem choć poddawany jest zewnętrznej presji – nie podlega zakłóceniom (ryc. 1). Podstawowymi parametrami stabilności są ekwifinalność, stałość, bezwładność, odporność i elastyczność (ryc. 2).

W literaturze przedmiotu można wskazać dwa podstawowe podejścia do stabilności środowiska. Pierwsze z nich to podejście „przyrodnicze"; w tym ujęciu krajobraz stabilny to krajobraz, w którym struktura i funkcjonowanie nie ulegają znaczącym, nieodwracalnym zmianom (Gigon 1983; de Fonseca 1990 i in.). Drugie podejście można określić jako „utylitarne"; zgodnie z nim środowisko stabilne jest przydatne do gospodarczego wykorzystania i stwarza możliwość długoterminowego, „bezpiecznego" korzystania z jego zasobów (B. Messerli 1983, P. Messerli 1983, Winiger 1983, Fuentes 1984, Getahun 1984, Kienholz, Hafner, Schneider 1984). Niektórzy badacze podejmują próby syntezy obu tych podejść (Kienholz, Hafner, Schneider 1984). Zarówno podejście „przyrodnicze" jak „utylitarne" można uznać za obiecujące badawczo. Mimo potencjalnie bardziej utylitarnego charakteru drugiego podejścia, oba stwarzają zbliżone możliwości wykorzystania uzyskanych wyników dla potrzeb praktycznych, czego dobrym przykładem jest opracowanie A. Gigona (1983).

Badania stabilności krajobrazu winny poszukiwać odpowiedzi na dwa zasadnicze pytania: o trwałość środowiska w sytuacji, gdy nie występują znaczące bodźce zewnętrzne oraz o sposób reakcji środowiska na znaczące bodźce zewnętrzne.

Nasuwają się następujące możliwości badawcze:

– Metoda porównawcza – określenie stanu środowiska w różnych momentach czasowych (najlepiej maksymalnie odległych od siebie). Służy głównie badaniom stałości środowiska.
– Przeprowadzenie ciągu obserwacji stanu środowiska – określenie kierunku przemian środowiska stanowi ważną przesłankę dla określenia jego stabilności.
– Badania podatności środowiska, traktowanej jako przeciwieństwo stabilności. Badania tego typu pozwalają na wnioskowanie o stabilności geosystemów, które (jeszcze) nie uległy zmianom.
– Zastosowanie wskaźników (miar) stabilności. Pozwala na porównywanie ze sobą różnych czynników zarówno jakościowych, jak i ilościowych, które określać mogą zarówno „skłonność" środowiska do podlegania zmianom (podatność), jak i sygnalizować zachodzące rzeczywiście – pod wpływem zewnętrznych bodźców – zmiany struktury środowiska, jego organizacji i funkcjonowania.

Obok wymienionych wyżej metod, poważne możliwości wydają się tkwić – mimo różnych ograniczeń – w eksperymentach badawczych i symulacji komputerowej. Pełne zastosowanie tych metod w badaniach stabilności środowiska jest jednak kwestią – być może nieodległej – ale jednak przyszłości.

Słowa kluczowe: geoekologia, podatność, stabilność, środowisko przyrodnicze

Key words: geoecology, susceptibility, stability, natural environment

The concept of stability

Among the many research problems of the widely understood geoecology, relatively little attention has been – up till now – paid to the issue of stability of the natural environment. Richling, Solon (1998), quoting numerous authors (among others, Hurd et al. 1971; Sutherland 1981; Bucek, Lacina 1985; Jurko 1987, Toccolini 1991), define stability (from Lat. *stabilis*) of a system as *durability* (*i.e. invariability of intrinsic characteristics*) *under the conditions of invariable surroundings and a capability to return to the original state after the disturbing external factors have ceased.* On that basis Malinowska, Lewandowski, Harasimiuk (2004) define landscape stability as *durability, resistance of landscape to the action of external factors and an ability to return to the primeval state.* According to that approach research upon stability of the environment is based on the systems theory, assuming that the environment of a certain area may be treated as a geosystem or a set of geosystems. The system approach assumes that the natural environment (landscape) constitutes a whole, being something more that a sum of components; features and relations between them consolidate the "whole", i.e. a geosystem (Chorley, Kennedy 1971, Trepl 1993, Pietrzak 1998).

Considering the natural environment as a geosystem, attention should be paid that it is not a system fully identical with systems described by a mathematical language; since the essence of natural processes differs significantly from the essence of mathematical functions, for which the definition of stability quoted above was created. Nature, environment, landscape – they are dynamical "beings", constantly undergoing changes of various kinds. Stability of geosystems is a dynamical stability – stable geosystems undergo revolutionary changes, but they are characterized with a fixed kind of functioning (Widacki 1979b). Thus a complete durability of nature or landscape – even under the conditions of invariable surroundings – does not exist; since with the passing of time the environment undergoes changes of various kinds. The more we cannot talk about a complete return to the original state after the action of disturbing factors have ceased. Even passing over the problem – what is the original state to the environment, the environment may, at the most, return to a state similar to the previous one, existing before a disturbance occurred. Therefore the stability of the natural environment may be defined as a degree of its durability under the conditions of invariable surroundings and a capability to return to a state similar to the previous one after the action of disturbing factors have ceased.

Disturbance factors

Disturbance factors influencing the environment or landscape are named with several, partly overlapping terms. The most frequently used one is the term stimulus, which is most generally explained as a factor evoking a reaction of "something" (Sobol 1995). The term pressure may also be used, mainly regarding human actions (anthropopressure). Another term being used is disturbance; *it may be explained as any single event upsetting a geosystem. A similar phenomena, but of a continuous character, may be termed as* stress (Grime 1979, Turner et al. 1988). Richling, Solon (1998) rightly draw attention to the relativity of the terms – disturbance and stress; depending on a time scale and kind of geosystem subject to an action the same event may be considered as single or continuous. Hence, the authors use the uniform term disturbance, describing both continuous and single actions. It seems nevertheless necessary that the concepts of a stimulus and a disturbance should be considered separately. An action upon a geosystem is one thing, the effects that it evokes in a geosystem are another. An important property of geosystems is a capability to put up a certain resistance to an acting stimuli i.e. inertia. Inertia makes it possible to eliminate some stimuli or to spread the reaction over a certain time (Widacki 1979a).

An external action upon a geosystem may be then termed as a stimulus; stimuli may (but do not have to) evoke specific effects in a geosystem. The term stimulus may be identified with the term stressor, sometimes used in biological sciences. The specific effects of those actions are disturbances. Stimuli should not be identified with disturbances at least because of the reason that if a geosystem does not submit to stimuli, it does not change (it "rejects" a stimulus) and even though it is subject to external pressure – it does not undergo disturbances (fig. 1). The term pressure, in turn, should be used exclusively as regards human actions.

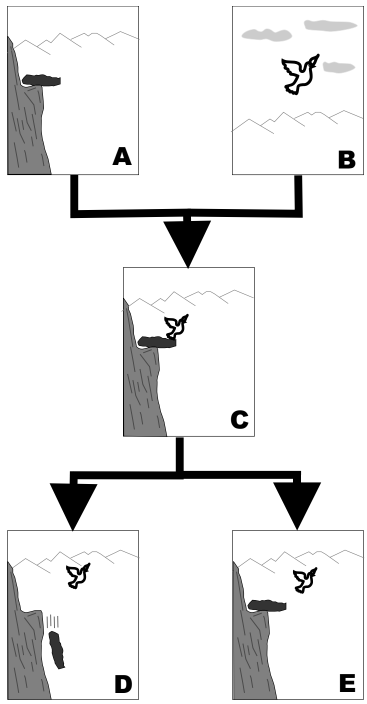

Fig. 1. A model of a geosystem – stimulus – disturbance relation
Explanations: A – geosystem, B – stimulus, C – stimulus action, D – disturbance, E – stimulus rejection

Ryc. 1. Model relacji geosystem – bodziec – zakłócenie
Objaśnienia: A – geosystem, B – bodziec, C – oddziaływanie bodźca, D – zakłócenie, E – odrzucenie bodźca

Partial and general stability

There are two different approaches to the concept of the stability of the environment that can be distinguished in literature. According to one, represented, among others, by Ružička et al. (1983), only a "partial" stability exists, thus a stability in relation to something – specific stimuli occurring or possible to occur in a given situation. According to that approach (Richling, Solon 1998) stability does not exist as a universal value, being rather an operational concept; it can be said that stability understood that way determines a reaction of the environment to the manifestations of various physicogeographical processes. It is worth pointing out that stable in relation to something in practice means resistant to something (e.g. a rock resistant to weathering, a species resistant to temperature fluctuations, a landscape resistant to anthropogenic changes). Thus, the approach being described narrows the concept of stability, bringing it close to the concept of resistance.

The other approach assumes a possibility to distinguish a general stability, so in relation to all actions possible (Richling 1976). That approach is represented by numerous authors (Messerli 1983, Pfister 1983, Fuentes 1984, Getahun 1984, de Fonseca 1990, et al.). Kondracki, Richling (1983) shortly define landscape stability as resistance to all changes. In that approach stability constitutes one of the general properties of the natural environment – it is "stability in general", not only "stability in relation to something". That attitude extends stability to a rank of a universal concept, a "comprehensive" one, we could say. Stability understood that way belongs, or at least should belong, to basic research issues of landscape ecology.

Parameters of stability

Richling, Solon (1998) point out five major properties of systems, which make up the concept of stability. They are: equifinality, constancy, inertia, resistance and elasticity. We can label those properties as parameters of stability (fig. 2).

The most general parameter of stability is equifinality – an ability to achieve the same final state within development under different starting conditions and in a different way (Bertalanffy 1984, after Richling, Solon 1998). It is worth reminding that in geosystems a return to a state identical with the starting one (i.e. equifinality *sensu stricto*) does not occur. Hence, in the case of natural research, equifinality denotes whether at all and to what degree (fully, partially) the environment is able to return to a state similar to the initial one after a disturbance has ceased (fig. 2, phases A–H). Then a question emerges, what can be described as a state similar to the initial one. Making use of a thesis by C. de Fonseca (1990): *A landscape is stable as long as its present organization lasts* we can assume that a geosystem similar to the initial geosystem ought to have a similar structure, way of functioning and direction of development. It does not matter whether those properties survived the action of a stimulus or they have been "regained" by a geosystem due to the process of relaxation (Widacki 1979a). Thus, geosystems characterized by a large degree of equifinality maintain their organization and are able to return to states similar to the initial ones even in spite of very strong disturbances, formed under the influence of strong stimuli. And the other way round, geosystems of low equifinality easily change their organization and do not return to states similar to the initial ones, even if the action of a stimulus is relatively weak and the disturbance, formed due to its action, insignificant.

The other parameters give more detail to the concept of stability. Constancy denotes durability (invariability) of a system within a certain period of time (Malinowska, Lewandowski, Harasimiuk 2004). As regards natural phenomena, durability is definitely a better term than invariability. That is because geo-

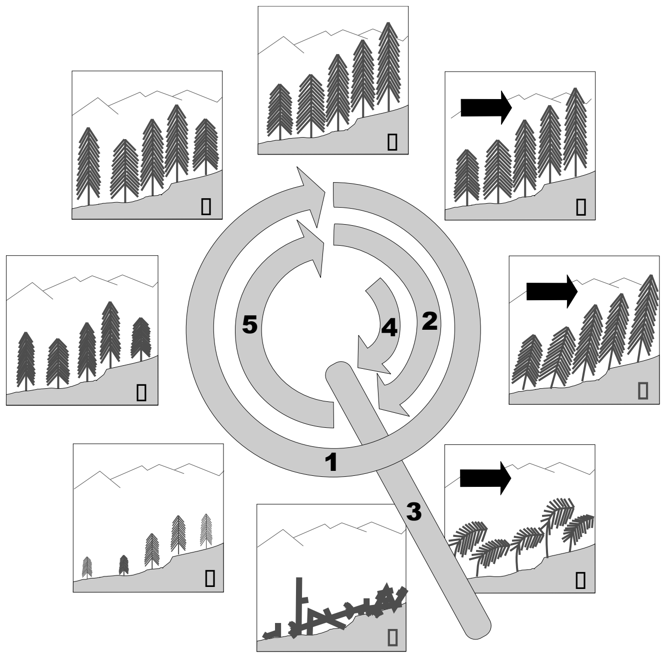

Fig. 2. Parameters of stability
Explanations: A–H Stages of a geosystem's development; 1 – equifinality, 2 – constancy, 3 – resistance, 4 – inertia, 5 – elasticity

Ryc. 2. Parametry stabilności
Objaśnienia: A–H Stadia rozwoju geosystemu, 1 – ekwifinalność, 2 – stałość, 3 – odporność, 4 – bezwładność, 5 – elastyczność

systems even within short periods of time are not fully invariable (Widacki 1979b). Unless transformations occurring in them cause a violation of a geosystem's organization, it can be described as durable (not invariable, though). It is worth paying attention to the importance of a time scale. In figure 2 stability characterizes the geosystem in phases A to D; in phase E it is characterized with a completely different organization. However, considering a similar geosystem from a wider perspective (phases A to H), we can regard it as durable (as it is able to return to its previous organization), and the disturbances occurring in the meantime – as episodes of little significance.

Resistance is most often defined as a threshold value for the parameteres of a system's surroundings, at which the system does not change or its changes are reversible after the disturbance has ceased (Sutherland 1981, Halpern 1988). In some definitions a "system's surroundings" is replaced with a "system" itself (Malinowska, Lewandowski, Harasimiuk 2004); according to that those threshold values are inherent in the object subject to a disturbance and not in e.g. the stimulus (e.g. in its increasing force). It seems that, as regards geosystem stability, those threshold values, after exceeding which a disturbance occurs, should be sought in the relation: stimulus's force – geosystem characteristics. In figure 2 it occurs between phases D and E. Hence, resistance would be best defined as a threshold value of the parameters of the stimulus – geosystem relationship, at which the organization of the geosystem does not change or the changes are reversible after the action of the stimulus has ceased.

Inertia is a parameter occurring only in the case of some geosystems and some kinds of disturbances. Inertia can be defined as a delay of reaction to a stimulus; a change of the organization of a geosystem occurs after some time after the appearance of a stimulus and it results not from a change in the stimulus-geosystem relationship (e.g. an increase in the force of a stimulus) but from the long time of the existence of that relationship (fig. 2, phases B-D). It can be said that the appearance of a disturbance is then an effect of a geosystem's "fatigue" (analogical to material fatigue in buildings and technical appliances), exposed to long-lasting, continuous influence. It is worth paying attention that inertia can be described only in the case of geosystems which really have been disturbed; if even a long-lasting pressure does not cause an exceeding of the threshold of a geosystem's resistance, the parameter inertia has no more reason for existence. Widacki (1979a) uses the term reaction time to describe the period between the moment of a stimulus's action and a geosystem's reaction to the stimulus. Let us note that the end of that period can be both a disturbance as well as a "rejection" of the stimulus by the geosystem.

Elasticity denotes the rate, the way and the degree in which the initial characteristics of a system are reconstructed after the occurrence of a disturbance (Richling, Solon 1998). A period, within which a return to a state similar to the initial one (fig. 2, phases E to H) takes place, is called a period of relaxation (Widacki 1979a). Over that time a geosystem reconstructs the organization it had before the occurrence of a disturbance. The length of a relaxation period depends on, among others (Chorley, Kennedy 1971): the current state of a geosystem, resistance of particular parts of a geosystem (e.g. resistance of the environment's elements) and the geosystem's degree of complexity. A term similar to elasticity is resilience; that concept is used, among others, by Fuentes (1984) in the research upon the influence of man on the functioning of ecosystems.

Susceptibility of the environment

The set of properties discussed above constitutes a fundamental, from the viewpoint of the research upon stability, feature that can be labelled as susceptibility of the environment. It can be defined as the environment's ease to submit to various stimuli (Balon 2001). In a certain sense susceptibility is the opposite of stability: more stable geosystems are less susceptible to various stimuli and are characterized with a greater degree of durability. Less stable geosystems are more susceptible to stimuli and therefore submit to disturbances of various kinds with a greater ease (Pfister 1983).

It is worth noticing that a geosystem's reaction to a stimulus (fig. 3) depends both on the characteristics of the geosystem itself as well as on the kind of stimuli influencing the geosystem, their force, way and length of their influence (Balon 2001). A weak stimulus may cause a similar disturbance in a geosystem of little stability as a strong stimulus in a gesosystem of a large degree of stability (fig. 3, cases B and C). Thus, a basic importance for stability should be attributed to the relation between the force of a stimulus and a geosystem's susceptibility.

The concept of susceptibility is similar to sensitivity and ecological lability by A. Gigon (1983), yet both the terms are used mainly regarding the biotic

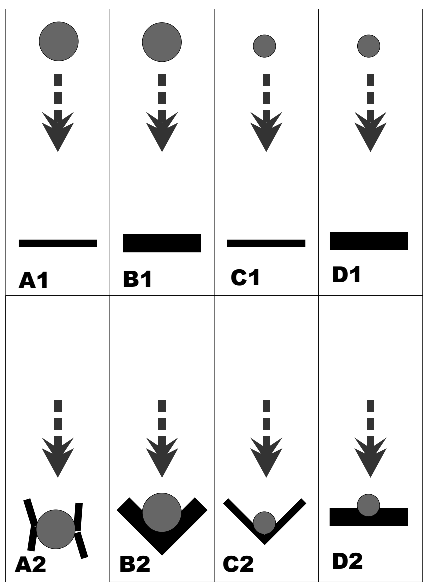

Fig. 3. A model of a relation: stimulus force – geosystem's susceptibility
Explanations:
A1–A2 Strong stimulus – high susceptibility
B1–B2 Strong stimulus – low susceptibility
C1–C2 Weak stimulus – high susceptibility
D1–D2 Weak stimulus – low susceptibility

Ryc. 3. Model relacji: siła bodźca – podatność geosystemu
Objaśnienia:
A1–A2 Silny bodziec – duża podatność
B1–B2 Silny bodziec – mała podatność
C1–C3 Słaby bodziec – duża podatność
D1–D2 Słaby bodziec – mała podatność

part of the environment, unlike susceptibility used both for the abiotic and biotic components (Varsavova 2003).

Natural and utilitarian approach

In the subject's literature it is possible to distinguish two main approaches to the stability of the environment. One of them is the "natural" approach; according to that attitude a stable landscape is a landscape, in which structure and functioning do not undergo significant, irreversible changes (Gigon 1983, de Fonseca 1990 etc.). The other approach can be described as "utilitarian"; according to that a stable environment can be useful for economic activity and enables a long-term, "safe" use of its resources (B. Messerli 1983, P. Messerli 1983, Winiger 1983, Fuentes 1984, Getahun 1984, Kienholz, Hafner, Schneider 1984). M. Winiger (1983), for example, states that the main rationale for distinguishing stable ecosystems is their durability within the span of at least two-three human generations. B. Messerli (1983) distinguishes four kinds of ecosystems as regards their stability: a stable ecosystem enables a long-term use of the environment's resources. A vulnerable ecosystem also enables a long-term use of the environment's resources but, to maintain stability, requires a particular caution in economic activity and a large input of "entry energy" (investment by man). In a fragile ecosystem economic activity may be carried out, but, to maintain stability, it requires a constant compensation with "anthropogenic energy". In an instable ecosystem it is virtually impossible to conduct any economic activity; even small changes introduced by man cause degradation of the environment.

Gigon (1983), representing the "natural" approach, distinguishes ecological stability, opposing it to instability. He defines ecological stability as an ecosystem's durability along with its capability to return to the initial state after a change has occurred. Depending on the kind of disturbance factors occurring and the appearance of disturbance oscillations – he distinguishes four types of stability: *constant, cyclic, resistant and elastic*. Ecological instability – a process of irreversible changes in a geosystem tied with a lack of capability to return to the initial state after the occurrence of a change – can be subdivided into *natural endogenous*, *natural exogenous* and *anthropogenic*. What should be noted is the distinguishing of endogenous instability; it implies that there exist instable ecosystems, where disturbances occur without the appearance of external stimuli, so to say – by nature heading for destruction, a change in their own organization. Apart from stability and instability A. Gigon distinguishes the already mentioned *ecological lability*, which he defines as an ecosystem's distinct proneness for irreversible changes.

Kienholz, Hafner, Schneider (1984) attempted a synthesis of the both approaches – the "natural" one and the "utilitarian" one. They distinguish the following types of areas: stable – possible for permanent use, capable to return to equilibrium after the occurrence of disturbances, instable – susceptible to disturbances, incapable to return equilibrium after the occurrence of disturbances "on their own" (without human intervention), conditionally instable – susceptible to disturbances in certain situations, for example under a too strong pressure by man, quasi-stable – potentially unstable, not submitting to disturbances thanks to an "anticipating" human intervention.

Both the "natural" as well as the "utilitarian" approach can be regarded as promising as far as research is concerned. Attention should be paid, however, that the "natural" approach is much closer to the definition of stability adopted in the introduction to the considerations herein. Moreover, in spite of a potentially more utilitarian character of the other approach, both of them create similar opportunities for the use of obtained results for practical needs. An example of that may be a paper by Gigon (1983) determining the rules of rational economic activity in areas characterized stability of a different kind.

Research upon stability – opportunities and methods

According to the adopted definition, research upon landscape stability ought to seek answers to the two crucial questions:

– About the environment's stability (durability of its organization – structure, way of functioning, direction of development) in a situation when any significant external stimuli do not occur.
– About the way of reaction of the environment (of its organization – structure, way of functioning, direction of development) to significant external stimuli.

It seems that the best way to answer the first question is to use the comparative method, and thus to describe the state of the environment at different moments of time (at the best, maximally distant from each other). It is not simple for various reasons. First of all, data concerning past states of the environment is difficult to obtain, and the available data is usually weakly comparable with what is possible to obtain at present. That regards both the comparativeness of the information itself as well as its carriers, e.g. the comparativeness of maps. Comparing two (or even several) states, besides, does not give a complete answer to the real course of events between consecutive states.

Therefore the comparative method can serve the research upon stability, but for the determination of other parameters of stability a regular research sequence is essential. Setting up such a sequence – as any investigations upon the environment's functioning and dynamics – requires, in turn, the engagement of large resources and energy. Moreover, research upon stability frequently does not have an isolated character; they rather ought to comprise certain areas e.g. a sequence of geosystems arranged along a slope catena; that issue is discussed in detail by Ostaszewska (2002). It seems that comparative research answer rather the question of a geosystem's durability or its transformation direction, however not fully the question of its stability; a knowledge of transformations may only be one of the rationales for the description of stability.

It is even more difficult – using the comparative method – to obtain a direct answer concerning the environment's way of reaction to a stimulus; investigations of that type require a complete sequence of data regarding the occurrence of a stimulus and the geosystem's reaction to it. Yet obtaining data on the environment's state directly before the action of a stimulus is a rare case. Such opportunities may and should be used, investigations, though, cannot be based mainly on a scientist's luck or intuition. For example, when we investigate a flood, without a difficulty we describe in detail the phenomenon's effects, with some portion of luck we'll obtain documentation concerning the flood itself, yet very seldom we have data of the same accuracy concerning the situation existing before the spate. Apart from that, stimuli influencing the environment may be of various kinds and it is difficult to wait with undertaking research until all of them have occurred. Thus the comparative method may seldom be fully useful in practice.

What appears much more promising is the research upon the environment's susceptibility considered as the opposite of stability. Determining a geosystem's susceptibility "to something" seems methodologically simpler than e.g. an investigation of resistance towards a specific stimulus. That is at least because of the fact that the determination of resistance requires, as a matter of fact, the appearance of a disturbance and the occurrence of tangible changes in a geosystem (or at least conducting such a simulation); in the case of susceptibility we can try and determine its degree, even in geosystems that have not (yet) undergone changes. Appropriately selected indicators of susceptibility can be used here.

In general, using indicators (measures) appears the research procedure creating the largest chance to obtain at least approximate knowledge of the environment's stability. It allows us to compare various qualitative and quantitative factors. They can denote both the environment's "proneness" to submit to changes (susceptibility, sensitivity) as well as indicate the actually occurring – under the influence of external stimuli – changes in the environment's structure, its organization and functioning. A detailed methodology of such investigations is still to be elaborated, best of all through using similar indicators in areas of possibly various characteristics of the natural environment and varied human pressure.

Beside the comparative method, research upon stability and determination of stability indicators, serious chances appear to be inherent – despite various restrictions – in research experiments and computer simulation. A full use of those methods in the investigations of the environment's stability, though, remains a question of – perhaps not distant – but still a future.

Conclusions

- Research upon the environment's stability is of an essential importance, both theoretical as well as utilitarian; hence stability ought to belong to the basic research issues of geoecology.
- Research upon stability ought to be preceded by setting the used concepts in order, so that they could be uniformly understood by scientists representing different disciplines, and also – which is more important – by the "recipients" of our investigations.
- Both the "natural" as well as the "utilitarian" approach to research upon stability create similar opportunities to use the obtained results for practical purposes.
- The frequently used comparative method enables us to determine the degree of the environment's durability or its transformation direction, durability, though, is only one of stability parameters and the direction of transformation may only be one of the rationales for the determination of stability.
- Promising opportunities are created by research upon the environment's stability, considered as the opposite of – weakly measurable – resistance.
- The research procedure presently creating the largest chances to obtain a knowledge concerning the environment's stability is using measures (indicators) of stability.
- Significant opportunities inherent in research experiment and computer simulation may be fully used no sooner than in a not distant future.

Tekst tłumaczył Andrzej Kacprzak

Bibliography

Balon J., 2001: *Podatność geosystemów górskich na zmiany antropogeniczne* [w:] German K., Balon J. (ed.), *Przemiany środowiska przyrodniczego Polski a jego funkcjonowanie*. Problemy Ekologii Krajobrazu, t. 10, IGiGP UJ, Kraków: 765–771.

Bertalanffy L., 1984: *Ogólna teoria systemów*. PWN, Warszawa: 340.

Bucek A., Lacina J., 1985: *The skeleton of ecological stability of landscape in landscape planning*, Proc. VII th International Symposium on problems of landscape ecological research, Pezinok.

Cancela de Fonseka J.P., 1990: *Quantitative analysis of landscape systems*. "Biulletin de la Societe de geographie d'Egypte", 63.

Chorley R.J., Kennedy B.A., 1971: *Physical Geography. A System Approach*. Prenitice-Hall Int. Inc., London: 1–370.

Fuentes E.R., 1984: *Human impact and ecosystem resilience in the Southern Andes*. "Mountain Research and Development", 4/1: 45–49.

Getahun A., 1984: *Stability and instability of mountain ecosystems in Ethiopia*. "Mountain Research and Development", 4/1: 39–44.

Gigon A., 1983: *Typology and principles of ecological stability and instability.* "Mountain Research and Development", 3/2: 95–102.

Grime J.P., 1979: *Plant Strategies and Vegetation Processes*. J. Wiley & Sons.

Halpern C.B., 1988: *Early successional pathways and the resistance and resilience of forest communities*. "Ecology", 69 (6).

Hurd L.E., Mellinger M.V., Wolf L.L., McNaughton S.J., 1971: *Stability and diversity at three trophic levels and terrestrial ecosystems*. "Science", 173.

Jurko A., 1987: *A contribution to ecological diversity of some plant communities*. "Ekologia" 4,4. Bratislava.

Kienholz H., Hafner H., Schneider G., 1984: *Stability, instability and conditional instability mountain ecosystem concepts based on a field survey of the Kakani Area in the middle hills of Nepal*. "Mountain Research and Development", 4/1: 55–62.

Kondracki J., Richling A., 1983: *Próba uporządkowania terminologii w zakresie geografii fizycznej kompleksowej*. "Przegl. Geogr.", 55/1.

Malinowska E., Lewandowski W. Harasimiuk A., (ed.) 2004: *Geoekologia i ochrona krajobrazu. Leksykon*. UW, Warszawa: pp 128.

Messerli B., 1983: *Stability and instability of mountain ecosystems: introduction to Workshop Sponsored by the United Nations University.* "Mountain Research and Development", vol. 3, no. 2: 81–94.

Messerli P., 1983: *The concept of stability and instability of mountain ecosystems derived from the Swiss MAB-6 studies of the Aletsch area*. "Mountain Research and Development", vol. 3, no. 2: 281–290.

Ostaszewska K., 2002: *Geografia krajobrazu. Wybrane zagadnienia metodologiczne.* Wyd. Nauk. PWN, Warszawa: 278.

Pfister Ch.,1983: *Changes in stability and carrying capacity of lowland and highland agro-systems in Switzerland in the historical past*. "Mountain Research and Development", 3/3: 291–297.

Pietrzak M, 1998: *Syntezy krajobrazowe. Założenia, problemy, zastosowania*. Wydawnictwo Naukowe Bogucki, Poznań: 168.

Richling A., 1976: *Analiza struktury środowiska geograficznego i nowa metoda regionalizacji fizycznogeograficzne.* Rozprawy UW, 104, Warszawa.

Richling A., Solon J., 1998: *Ekologia krajobrazu.* Wyd. Nauk. PWN, Warszawa: 1–320.

Ružička M., Jurko A., Kozova M., Žigrai F., Svetlosanov V., 1983: *Evaluation methods of landscape stability on agricultural territories in Slovakia*. "Ekologia", 2/3, Bratislava.

Sobol E. (ed.), 1995: *Mały słownik języka polskiego PWN*. Wyd. Nauk. PWN, Warszawa.

Sutherland J.P. 1981: *The fouling community ay Beaufort, North Carolina, a study of stability.* "American Naturalist", 118.

Toccolini A., 1991: *The evaluation of ecological stability as a key-system element in the rural planning process: method and application to an Italian area*, Proc. Europ. IALE-Seminar on Practical Landscape Ecology, vol. II, Roskilde.

Trepl L.,1993: *Towards a theory of urban biocoenoses; some hypotheses and research questions* [w:] Numata M., Sukopp H. (ed.), *Urban Ecology.* SPB Academic Publishing, The Hague.

Turner R.K. (ed.). 1988: *Sustainable Environmental Management. Principles and Practice*. Westwiev, Boulder, Colorado.

Varšavová M., 2003: *Abiocomplekxes of the Belianske Tatry Mountains and the proposal of ecological limits for tourism and recreation use* [w:] Pietrzak M. (red.), *Krajobraz – turystyka – ekologia*. Problemy Ekologii Krajobrazu, XI, Leszno.

Widacki W., 1979a: *Uwagi o funkcjonowaniu geosystemów.* "Folia Geogr., ser. Geogr.. Phys.", 12.

Widacki W., 1979b: *Relacja człowiek-środowisko jako zagadnienia sterowania.* "Przegl. Geogr." 51/4: 667–701.

Winiger M.,1983: *Stability and Instability of Mountain Ecosystems Definitions for Evaluation of Human Systems*. "Mountain Research and Development", vol. 3, no. 2: 103–111.