DOI:10.24425/igbp.2018.124892 PAPERS on GLOBAL CHANGE, 25, 57–74, 2018

THE RISK OF CATASTROPHES FOR CIVILISATIONAL DEVELOPMENT OF ENVIRONMENTAL ORIGIN

KONRAD PRANDECKI
Institute of Agricultural and Food Economics
National Research Institute
ul. Świętokrzyska 20, 00-002 Warszawa, Poland
e-mail: kprand@interia.pl

ARTUR MICHAŁOWSKI
The Polish Association of Environmental and Resource Economics
ul. Gramatyka 10/105, 30-067 Kraków, Poland
e-mail: arturmichalowski@wp.pl

ABSTRACT: The purpose of this article is to identify and assess environmental risks that may have the greatest impact on the future of humanity. They were divided into two basic groups, i.e. for natural processes and resources. In addition, climate change is described as different group. The authors decided, that a holistic approach to this issue is more desirable than dividing it into two above-mentioned groups.

The comparison of various threats was possible due to the application of identical assessment criteria, such as: the harmfulness, rate of spread, scope and moment of occurrence of a given group of threats. Each of the listed criteria has been evaluated on a five-point scale, where 1 has the smallest and 5 the largest impact force.

The obtained results show the leading importance of natural processes in maintaining the existing Earth system. In addition, the authors point to a greater risk of problems related to renewable resources than non-renewable one. As a result, it can be assumed that the current degradation of natural processes and excessive use of resources is likely to lead to the risk of global disasters.

KEY WORDS: environment, catastrophic risk, civilisational development, future studies, global threat.

INTRODUCTION[1]

Studies addressing the future often feature an aspect of threat. For example, publications of the *Polska 2000 Plus* Forecasting Committee include a paper on "Global threats as barriers to development" – *Zagrożenia globalne barierami rozwoju* (Kleer 2012; Kleer, Kleiber 2015), while foreign studies of this profile are also well known (Randers 2012; Wijkman, Rockström 2012). Among the numerous threats identified, a key group comprises the environmental threats; although in many cases activity ceases with the identification process, with no use then made as scenarios for the future are developed. Acting against that tendency, the authors here advance a thesis that, by the time the mid-21st century arrives, the natural environment may well be a key factor bringing about a global breakdown in humankind's civilisational development.

The aim here hast thus been to point to and assess those environmental threats that are capable of leading – at least in theory – to catastrophes for civilisational development even on the world scale. To this end, threats have been divided up into two main parts, relating to either natural processes or resources. In each of these it was possible to identify groups defined more precisely – which are the subject of discussion in a further part of this same study. Beyond that, it was accepted that effects will prove irreversible in the short or even medium terms, with the result that phenomena of this kind lead to a permanent "makeover" of human civilisation, with this being a consequence of the catastrophe, as opposed to a further element thereof.

Beyond that, as they worked to identify the aforementioned threats, the authors set themselves the goal of introducing a hierarchy of these that would make it possible to indicate factors potentially likely to prove the most dangerous.

RESEARCH METHODS

The considerations described relate to phenomena of a global (universal) nature, given that even those environmental disasters that are on a local scale may translate into issues of relevance to the entire population of *Homo sapiens*, on account of the universal nature of their occurrence. This is what justifies the treatment of humankind as a single collective entity[2].

---

[1] This article is an abbreviated (and English-translated) version of a text that went into the publication, in Future: World-Europe-Poland no. 2/34/2016.

[2] This kind of approach is a major simplification, but one that is nevertheless justified in this context on account of the Malthusian limitations that will make their appearance on the scale of the world as a whole. These will concern all societies, with the result that cultural and political divisions will lose their significance. A separate issue is decisionmaking in regard to protective action, given the differentiation or disparities that will most likely typify this.

The results presented here arise out of both a critical analysis of the subject literature and the authors' own research. The authors determined to introduce their own assessment of the phenomena described below, with basic criteria introduced to facilitate comparisons. In this way, each group of threats has gained appraisal from the points of view of harmfulness, rate of spread, scope and moment of occurrence. The last of these criteria denotes a forecast time at which the threats proper arise, or more specifically in fact the moment at which an impact for the planet as a whole can be seen to have reached its zenith and become most tangible.

More specifically, each of the criteria referred to gained assessment on a five-point scale, whereby 1 denotes a very limited threat; 2 a limited threat; 3 a moderate threat; 4 a major threat; and 5 a very major threat. Thus, for example, where the method is applied to the criterion of moment of occurrence, a 1 is awarded where a problem may arise around 2050, whereas something foreseen for as early as 2020 gains a 5. Likewise, the faster the rate of spread or at least the greater the scope of impact, the higher the value awarded to the assessment.

The authors are here aware that the precise evaluation of studied phenomena may not prove possible; but they nevertheless consider adoption of the above scale – even if associated with major simplifications – as offering a comprehensive look at future catastrophes, with the possibility of a hierarchy for events under study also being arrived at. Obtained result can then be treated, not as detailed analyses of particular areas, but as an attempt at a holistic, all-embracing approach to threats to the further development of human civilisation.

The work has taken in the 2015–2050 timeframe, with the results pointing to the possible appearance around 2030 (in the 2025–2035 period) of a series of phenomena important from the point of view of the work carried out. It is thus recognised that the year 2030 ought to be regarded as a turning point of some kind. In our view, what takes place here will be, not so much a one-off event, as an interweaving of many phenomena. For this reason, the work presented here has sought to draw a distinction between two sub-periods, i.e. from 2015 through to around 2030, and from 2030 to 2050.

Presented results were likewise assigned to the three areas of climate change, resources and natural processes. Climatic factors have been separated out as an issue, since these fall within both the resource- and process-related parts.

CLIMATE CHANGE AS A HOLISTIC ENVIRONMENTAL THREAT

Observations being made currently encourage a conviction that current climate change is of anthropogenic origin (IPCC 2013), with the source considered to lie in increasing emissions of greenhouse gases. Those taking such an assumption on board may also accept that the processes of hypothesis-testing and the devising of scenarios are precise enough to prove suitable for use in broader, multifaceted studies on the future.

Over the time perspective under study, the most probable scenario is considered to entail a rise in global temperature of some 1.5–2.5 degrees Celsius (IPCC 2013). However, at regional level, there may be far greater changes, not least in Arctic areas and in the north-east of Europe. The most limited changes are in turn anticipated for areas by seas and oceans.

From the human point of view, it is the consequences of these changes that are important. It is assumed that a 2-degree rise in temperature will not of itself give rise to a global civilisational collapse, even if it may – indirectly and on the regional scale – have a significant influence on conditions for life on Earth (Cowie 2009), up to and including increased death rates among human beings (Springmann *et al.* 2016; Stern 2006). Among consequences of fundamental importance, it is possible to mention an increased frequency of occurrence of violent weather phenomena (downpours, gales, floods and droughts), an acceleration of processes ongoing in vegetation, and a disturbance of processes involved in the cycling of water in nature.

Some effects of climate change are already observable, but it needs to be recalled that the consequences will not be uniform. A deterioration of the situation in some regions may be accompanied by improvements in others. Overall, though, it is recognised that there is a major risk of conditions for human existence worsening, in particular when it comes to access to food[3] (Prandecki 2014a; Prandecki *et al.* 2014; Springmann *et al.* 2016).

In addition, it proves possible to identify links between climate change on the one hand and ecosystem metabolism or biogeochemical processes on the other. What emerges from this is a depiction of the ecosphere as an integrated biogeochemical and meteorological system. The changes ongoing within it are non-linear in character, and may thus give rise to consequences much greater than has been anticipated.

The international community is seeking to play an active role in counteracting ongoing climate change. However, the initiatives taken up do not seem effective. Research points to a steady overall rise in emissions of the greenhouse gases regarded as the main cause of climate change. Forecasts also confirm maintenance of the trends noted so far through to around 2030–2035, at which point there will most probably be a peak reached for anthropogenic emissions of greenhouse gases. Bearing in mind a certain inertia and non-linearity to climate-related processes (a time-lag operating between cause and effect), it is only around 2040 that we might envisage real processes holding back further climate change. In consequence, the most probable circumstance

3 The period up to 2050 is forecast to witness an increase of the human population to around 10 billion people. In line with the fact that this growth will coincide with ongoing changes in eating habits, it is forecast that demand for food will end up being at almost twice the level it is today. However, many studies suggest that the increase would need to be far less than this if only waste in the course of production, processing, transport and consumption can in some way be reduced. However, all that is not going to be easy to achieve. Furthermore, changes affecting the accessibility of the resources needed to be produce food are such that it seems reasonable to assume climate change exerting a negative influence on food security.

through to 2030 is a scenario in which a policy of continuation/business-as-usual is maintained, with protective initiatives only coming on stream later. This also denotes a crossing of safe global boundaries for climate change in mid-century, with numerous negative consequence therefore arising.

THE INFLUENCE OF NATURAL RESOURCES ON THREATS TO CIVILISATIONAL DEVELOPMENT

In the context of analysis of future environmental threats it is the problem of resources that is raised most often. The literature on natural resources draws a distinction between five main areas in which civilisational catastrophes have a risk of arising. These relate to shortages and/or inadequate management of water, degradation of soil and excessive use of nitrates and phosphorus compounds, the consumption of energetic raw materials, the consumption of rare earths and the loss and degradation of biodiversity.

By far the easiest aspect to estimate is the exhaustion of non-renewable resources. Typically, the research method here sets available supplies of a given resource against current rates of utilisation. To improve the reliability of these estimates, both elements in the equation can be subject to revised estimates – in line with either the discovery of new supplies or a change in rates of consumption. And while the analyses involved remain rather generalised, they do allow for at least an approximate indication of when a given resource is likely to be exhausted. On this basis, the supplies needing to be seen as most threatened are those of rare earth metals, silver, gold, zinc and lead, as opposed to the fuels and energy sources of the popular imagination (Prandecki 2013).

It needs to be stressed that the above means of estimating resources are very imprecise, though at least they allow for the determination of the relationship pertaining to access to given resources. At the same time, a decline in levels of resource extraction can be accepted as raising market prices, with the potential effect of demand being reduced (as the poor will not be in a position to meet their needs, but will be forced to seek out substitutes), while the period of resource accessibility among the rich is simultaneously extended[4].

Moreover, it is still possible to anticipate new deposits being found, as well as more efficient ways of exploiting existing ones, with this also having its effect in extending availability (Prandecki 2013, 2014b).

The situation regarding renewable resources looks a little different. For example, the resource of fresh water suitable for drinking represents just 0.8% of all accessible water (excluding that locked up in ice sheets). A majority (some 70%) of the water consumed by people goes on agriculture. Industry accounts for about 20%, households for ca. 10% (WWAP 2015). However, these estimates are rather generalised, as there

4 Assuming that tensions do not arise, leading to a revolution of the poor against the rich.

is no one dominant method of calculating water consumption (Gerten *et al.* 2015; Jaramillo, Destouni 2015). Today, an estimated 663M people in the world (9% of the entire population) have no access to improved drinking water (WHO 2015). This is actually the lowest result recorded in history, making it clear how the situation has improved. However, other work shows that – as of 2008 – a physical lack of water or water poverty[5] was being experienced by around 2.8 bn people (Ercin, Hoekstra 2014).

Water problems may reflect a series of factors, i.e. rising consumption, improper management, pollution, a lack of water in general, or climate change. And here, particular attention needs to be paid to improper water management. This is linked with the wasting of resources or the excessive consumption thereof. The best example of this is the destruction of the Aral Sea.

Forecasts on access to water leave little room for optimism, with the UN Secretary-General assuming that these kinds of problem might even be affecting 3.9 billion people by 2030 (Lean 2009; RT 2013). That is almost half of the entire forecast population. Such estimates make clear the growing significance of water to the economy and human existence. It is anticipated that, by 2050, there will have been a 20% increase in the amount of water consumed by agriculture (assuming a business-as-usual scenario). Furthermore, the assumption is that water use will grow even faster than the human population (UN Water 2015).

Soil is of great importance to human life, given the many functions served in the environment, and the many services provided. After Gruszczyński (2014), these can be taken to include biomass production; chemical stabilisation and the filtration of pollutants (with sorption taking place);the transformation of certain chemical components and storage of water; the safeguarding of conditions for biodiversity to exist and flourish (in a range of soils and soil habitats); the accumulation of soil organic carbon (SOC); the protection of Earth's geological, palaeontological and archaeological heritage; and the safeguarding of a physical and cultural environment suitable for human activity.

From the resource point of view, what matters is accessibility of soil in a form that ensures biomass production, and hence the capturing of energy for the supply of both fuel and food. However, many means by which people manage the Earth's surface are such as to lead to losses of the substances and properties that make the life and growth of suitable species possible. The processes involved here include erosion of soil by water and the wind, mass movements, the loss of organic carbon, pollution by noxious substances (like heavy metals, but also in this context even salt), the sealing-off of the soil surface and compaction.

To simplify greatly, we can assume that soil matters to people from a production-related point of view. This ensures the priority status assigned worldwide to measures that limit

[5] Water poverty is understood as the lack of capacity (financial means) to obtain water, i.e. by the digging of wells, the building of transmission systems or the effective management of infrastructure of these kinds.

erosion, help maintain the balance of organic substances, and stabilise and uphold the processes by which nitrogen, phosphorus and potassium all cycle[6].

Biological diversity "means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part" (*Convention on Biological Diversity* done at Rio de Janeiro on June 5th 1992). It can assume many forms (Prandecki and Sadowski 2010, 30), including "genetic diversity relating to the multiplicity of genes present within different species; but also species diversity among plants, birds and other animals, as well as microorganisms; and ecological (ecosystem) diversity – i.e. the configurations arising out of the co-existence of species forming a multitude of ecosystems and landscapes; biogeographical diversity – looked at in relation to geographical location globally; and landscape diversity, with it then being necessary to recall that a landscape may be a natural one, or a cultural one shaped by human beings".

Just one of many examples of the significance of biodiversity for humankind, albeit a key one, involves the presence of pollinating insects. Pollination by animals is key for 87 out of 124 main crop-plant species. This leaves around 35% of human food of plant origin dependent on pollinators (Klein *et al.* 2007). Should pollinators be lost, the costs would thus be absolutely immense (Majewski 2014), and the process would of necessity drive a fundamental change of human diet, and major changes in the availability of food. The degradation of biodiversity may also influence other resources, as when the felling of forests reduces capacity to retain water, and hence people's access to that key resource also.

In the *Living Planet Index 2014* report, it was emphasised that, overall – in comparison with 1970 – the population of thousands of vertebrate species has declined by 52%. Furthermore, observations indicate that the process is intensifying (WWF 2014). The scale of the phenomenon is so great that the ongoing change is now being termed the "Sixth Great Extinction". And, unlike in the case of the other 5, this one will result entirely from the activity of a species – our own. A characteristic feature of this event is the speed with which it is taking place – quite unprecedented in the Earth's history. It is primarily the natural ecosystems – as opposed to those we have shaped ourselves – that are being lost. Particular problems here relate to the tropical forests of Latin America and Africa (Petersen *et al.* 2016), which are of course of immense importance to biodiversity. Deforestation thus equates closely with biodiversity loss, and satellite data for 2014 make it clear that around 18 million hectares of forest were lost in that year alone – an area the size of Portugal (Petersen *et al.* 2015).

Analysis of literature relating to marine management suggests a lack of studies assessing the risk of loss of balance where marine resources are concerned (Béné *et al.* 2016). However, populations of many different species in the sea are known to be in decline, and this is particularly true of those exploited by human beings.

[6] The first of these elements is of particular significance. It needs to be present in a plant--assimilable form.

Far harder to assess is what this can be said to mean overall for homeostasis in marine ecosystems.

THE DESTRUCTION OF NATURAL PROCESSES AS A THREAT TO CIVILISATION

A key aspect of current and future threats to civilisation is what can be seen to arise from the process-related (dynamic) analysis of the Earth's ecosphere from the ecosystem homeostasis point of view. In this article, this kind of homeostasis is treated as the dynamic equilibrium present globally on the basis of natural positive or negative feedback processes. When conceptualised as a mathematical function, the homeostasis in question is seen to be of an absolute nature. Where Earth's ecosphere and its component spheres are considered, we should accept that this is a concept of both modelling and operational significance, which is found to encompass a host of non-linear natural processes.

Homeostasis can be seen in terms of its properties, of which the most important include equifinality, constancy, inertia, resilience and elasticity (Richling, Solon 2011). Equifinality may be boiled down to the idea that an ecosystem achieves a defined final state having perhaps started off with quite distinct and non-uniform initial conditions, and then proceeding via a range of different processes. Constancy in turn denotes ecosystem persistence over a defined time interval. In fact ecosystems change over periods that differ greatly – from millennia in the case of mountain systems, via hundreds of years for forest ecosystems to just years when it comes to the biocoenoses of littoral zones in waters. Of course, ecosystems are never entirely constant in any case, given the presence of both fluctuation in the shorter term and evolution over the very long term.

Inertiais associated with delayed onset of change in ecosystem elements and processes, even in the presence of disturbing or disruptive impacts. Resilience then relates to threshold values for parameters present in the surroundings of ecosystems, up to which no change within takes place at all, or else change takes place in such a way as to remain reversible should disturbing factors dissipate. However, if external impacts are too great, then one ecosystem transforms into another that is better adapted to the circumstances faced. Elasticity denotes the rate and/or means by which initial characteristics of an ecosystem can be returned to. It is thus associated with a rebound time for the return to the initial state.

The subject literature identifies many natural and anthropogenic factors that influence ecosystem homeostasis. Crucial among these is ecosystem maturity and diversity, as associated with numbers and strengths of linkages, as well as external disturbances (Richling, Solon 2011). Where the maturity of ecosystems is concerned, there is no overall mechanism by which this can be related to homeostasis. It is stressed that the shaping of ecosystem maturity is accompanied by changes in the life attributes of species.

Attention is also paid to increased stability of ecosystem structure as a result of a reduction or increase in amounts of organic matter.

Research also shows that a more mature (diverse and complex) ecosystem displays reduced resilience in the face of disturbance and takes longer to rebound. A further discovery is that a change in the relationship between elements and processes present in an ecosystem (with high diversity, increased food-chain complexity and lengthened matter cycling) all lead to the development and complication of feedback systems, and thus to stability and homeostasis.

In the linkages between maturity and stability it is quite frequent for the key factor to relate to external disturbance to ecosystems. Many times in the literature it is possible to see prominence given to some straightforward linkage between homeostasis and biodiversity in ecosystems. This is simply too great a simplification, however, arising as it does from a superficial analysis of the 1976 model from M. Tansky. In his model, constancy of composition and resilience in an ecosystem can be seen to rise with the number of paths via which energy flows, as well as the number of linkages between these, and a more even share of different elements among the overall energy resources, abundance and area. It has further been noted that a direct relationship between homeostasis and biodiversity cannot exist, as these are controlled by environmental heterogeneity and dependent upon the density of the network of connections. A further factor that can exert an influence on ecosystem homeostasis is size. The smaller the ecosystem, the more its area is subject to external impacts. A reduction in the size of an ecosystem is also associated with its impoverishment, and hence with a decline in its capacity to achieve homeostasis.

Where external disturbances are lacking, further conditioning is achieved by the number and strengths of network connections, though total number is not key here, given the way ecosystem stability appears to rise where certain functional modules only more loosely connected to one another have come into existence within the system. In any case, the influence on biodiversity and ecosystem homeostasis exerted by external disturbance is not found to be uniform in nature.

In a general sense, disturbance can be classed as spreading within one type of ecosystem or in a range of different ecosystems. Moreover, in the literature, it is typical to come across the idea that a moderate level of disturbance can actually bring about an increase in biodiversity across space. Indeed, it is deemed to be in this way that the elasticity and resilience of ecosystems in the face of disturbances are shaped. Effect is given to this mechanism in defined conditions, as disturbance reduces the role of the commonest elements of an ecosystem, while not exerting an influence on the rare ones. The impact of disturbances is to leave resources in an ecosystem unused; and this offers hitherto-untapped opportunities for ecosystem resources to be utilised. Where these conditions go unmet, the biological diversity of an ecosystem may remain unchanged or diminish.

The global homeostasis of our planet's ecosphere can be looked at from the point of view of a dynamic equilibrium being present in its metabolic processes. This is all driven by living organisms whose "motivation" is to produce more copies of themselves. The utilisation of natural resources, energy and information present in the natural environment is essential if that is to happen, while evolution over time allows organisms to develop diverse metabolic strategies to achieve this. However, the resources present for use in the ecosphere are finite in nature, albeit capable of long-term cycling and recycling via well-identified biogeochemical cycles, as well as the hydrological cycle. The use of the resources in question may assume many and varied forms, however, with carbon compounds for example serving as building material and power source – sometimes at one and the same time. The metabolic reactions being run by all of the Earth's living organisms sum together to constitute the twin global processes of the production and decomposition of biomass. And a global equilibrium between these is preserved thanks to the homeostatic workings of a host of negative and positive feedbacks (Weiner 2015).

There are two reasons why ecosystem stability is a matter of importance for humankind. In the first place, rapid large-scale changes may cause conditions favourable for life to be lost. Beyond that, there is the fact that many natural processes are important for the economy, and thus capable of being regarded as environmental services[7]. The latter are treated as externalities from the economic point of view (Prandecki *et al.* 2015), and are thus not subject to market valuation. This in turn means that they are often left out when the future of human civilisation is considered. Of course, they are in fact highly significant for the environment and the economy alike, and more and more attention to this fact is now fortunately being paid (Buks, Prandecki 2015; Michałowski 2011, 2012, 2014, 2015). Nevertheless, the need remains for analysis to take in these processes in the context of the risk of disaster arising.

In this study seeking to assess groups of natural processes, a series of factors identified were deemed to have a major influence on the maintenance of homeostasis on Earth[8]. The choice was made in line with fundamental knowledge in the fields of biology and ecology (see, for example, Begon *et al.* 1996; Begon, Mortimer 1999; Colinvaux 1993; Cotgreave, Forseth 2002; Krebs 1996; Łomnicki 1988; MacArthur, Connel 1971; Odum 1977; Remmert 1985; Richling, Solon 2011; Ricklefs 1990; Townsend *et al.* 2003; Uchmański 1992; Weiner 2015). For this reason, and on account of the limited size of this text, as set against a multiplicity of factors[9], these did not gain more detailed characterisation in this study. The factors referred to were assessed using the method presented in the earlier part of this text; with obtained results allowing for a collective estimation indicating groups of processes and appraised threats.

[7] For a broader treatment of environmental services, see Michałowski (2013).

[8] A full list of the factors referred to in the research gained publication in Prandecki, Michałowski (2016).

[9] The assessment related to 35 factors, among which some gained consideration many times, in the context of different groups.

RESULTS

The authors' analyses and considerations have yielded an expert conceptualisation and assessment of the risk that factors of natural origin will generate a global civilisational catastrophe. The considerations were twofold – in relation to resources (Tab. 1) and processes (Tab. 2).

Under the first category, it proved possible to distinguish five groups in which threats might be present, relating to energy sources, rare earths, water, soil[10]and biodiversity. In the second group, processes considered to occur were sub-divided in relation to threats posed to the lithosphere, pedosphere, hydrosphere, atmosphere and biosphere. However, it was decided that – notwithstanding its previous characterisation as a phenomenon bringing together many processes and resources – climate change would not be the subject of separate assessment.

Furthermore, in the case of each of the groups of threats, part results were supplied, as well as an overall indicator of risk (Zp). The principles in line with which assessments were assigned are as presented in the Methods section applying to the study as a whole.

Table 1. Civilisational threats associated with natural resources

Group of resources*	Criterions				Overallindicator of risk
	harmfulness	rate of spread	range	time of occurrence	
Energy sources	2.5	2	4.0	1.0	9.5
Rareearths	3.0	2	4.0	3.0	12.0
Water	5.0	2	3.0	4.0	14.0
Soil	4.0	1	2.5	3.5	11.0
Biodiversity	3.0	4	2.5	4.0	13.5

* As a given group of resources may face several threats, the authors do not point to particular threats, but merely to resources with which threats may be associated. In this way, the group called "Water" is related to threats associated with both the hydrological cycle and pollution.

Source: authors' own elaborations.

Where non-renewable resources are concerned, the time of appearance of the risk of exhaustion or peak level of exploitation remains quite a long way away. It is not to be expected up to the year 2030, even in the case of the rare earths. In turn, where the non-renewable primary energy sources are concerned, the risk will not have arisen even by the end of the period under study.

However, a problem with the aforesaid rare earths may be encountered after 2030; and – furthermore – all of the non-renewables are likely to be associated with problems

[10] The group termed "soil" included criteria associated both directly (e.g. the organic matter balance) or indirectly (e.g. access to resources of nitrogen, phosphorus and potassium).

appearing quasi-globally. Limitations on supply will appear worldwide, and will have their impact on prices globally. Then, with a view to safeguarding their own supplies of raw materials, some countries may restrict trade in resources they possess themselves, with consequent influencing of the range of impact of the risk in question. In addition, the process will obviously make the situation faced by importing countries all the more severe, while reducing the impact on countries that happen to be richer in the given resource. It can be assumed that resources will not be exhausted at a very fast rate, though given deposits will come to be worked out steadily, with appropriate pressure to find substitutes then being exerted. It is thus difficult to assess how harmful this risk will actually prove to be.

The resources that are of the greatest significance (i.e. sources of energy and rare earths) are of priority status where the existence of contemporary civilisation is concerned. Without cheap and universal access to energy it is hard to imagine society functioning at all – in cities in particular. The existence of many substitutes and the development of the technologies by which renewable energy can be stored encourage a conviction that primary non-renewable energy might have its place taken, with the result that the degree of impact of this risk is assessed at a quite low level. Rare earths are in turn essential to the manufacture and operation of much modern ICT, including even that involved in health protection. In this case, the existence of substitutes is not certain, with the result that the risk is raised. However, a decline in the availability of resources would seem to go hand in hand with an increased level of recycling, the effect of this again being to reduce the assessment regarding degree of harmfulness.

There are many fears associated with the degradation of soils, given their status as a resource indispensable to the production of food. The assessment for the degree of harmfulness associated with this factor is thus a high-value one. However, this problem is only likely to spread slowly, while the range already occupied is small. Soil degradation appears to be ongoing at a steady rate, but real change is only noticeable over the rather longer term, after say 10–15 years at the least. This problem is also seen to arise regionally, and is in large measure dependent on agricultural practices. It is also associated with difficulties with determining time of onset. Soil degradation has already been ongoing for a very long time, and the spectacular example of the US "Dustbowl" in the inter-War period may be recalled. More often, however, this low-rate process is hardly visible at all, with it proving difficult to determine the moment at which degradation might be on such a scale that global catastrophe threatens. It would seem that – should a policy of *Business as Usual* be applied, there might be such a moment somewhere around 2030. In this regard, there are particular fears associated with safeguarding proper disposition of nitrogen, given that the natural cycling of this element was long ago breached by human activity.

The threats to biodiversity represent a very complex group – to the extent that unequivocal assessment is difficult. The rate of exhaustion of this resource would seem to be so high that it is possible to speak of the rapid emergence of problems in this sphere. However, references to biodiversity also require consideration of matters of water retention, the stabilisation of the climate, absorption of CO_2 and the production of oxygen. That fact leaves as justified the contention that the current, absolutely over-exploitative policy threatens visible harm by around 2030. Initially (as today), the biodiversity issues will be most tangible locally. However, in the longer time perspective global consequences may arise. Given the high level of complexity of the factor, an enhanced degree of harmfulness is recognised, but not yet one that capable of being termed "very great".

Furthermore, the loss of many species or even whole ecosystems may remain largely unnoticeable at global, biosphere level. At the same time, there is a risk that the destruction of some most key factor could give rise to far-reaching, non-linear effects, up to and including a destabilisation of the Earth system as a whole.

Table 2. The risk of occurrence of threats to civilisation brought about by the degradation of ecological processes

Group of processes		Criterions				Overallindicator of risk
		harmfulness	**rate of spread**	**range**	**time of occurrence**	
Threats to the	lithosphere	16/6 = 2.7	14/6 = 2.3	17/6 = 2.8	16/6 = 2.7	63/6 = 10.5
	pedosphere	33/10 = 3.3	29/10 = 2.9	30/10 = 3.0	38/10 = 3.8	130/10 = 13.0
	hydrosphere	20/6 = 3.3	19/6 = 3.2	19/6 = 3.2	22/6 = 3.7	80/6 = 13.3
	atmosphere	32/10 = 3.2	29/10 = 2.9	31/10 = 3.1	33/10 = 3.3	125/10 = 12.5
	biosphere	56/18 = 3.1	54/18 = 3.0	57/18 = 3.2	59/18 = 3.3	226/18 = 12.6

Source: author's own elaboration.

The presented results give rise to several conclusions. Above all, it needs to be noted that the threats associated with the degradation of natural processes prove to be as important as resource threats. Moreover, in many cases, a moment quite close at hand is foreseen, at which consequences arise from the ongoing degradation process; and there may be repeated occasions on which this happens more rapidly than the exhaustion of non-renewable resources – notwithstanding the fact that the latter have come to be associated most often with environmental crisis.

The most dangerous threats are seen to be those concerning the hydrosphere. Indeed, problems in this area are forecast to make themselves known rather rapidly now, most of all where people's access to water is concerned. It is worth noting how the threats linked to the hydrosphere are distributed evenly among the criteria adopted, which means, not only a non-distant time of appearance of threats, but also considerable harm done to society where the processes in question start to be lacking, as well as a high rate of spread and extensive ultimate range of occurrence.

When comparisons are with the threats facing the hydrosphere, only in the case of the pedosphere are higher indicator values noted – which is to say a still-earlier time of onset of the given threat. However, it is foreseen that problems in this regard will only spread far less rapidly.

The assessment of the aforementioned groups of threats (involving both resources and processes) gives rise to several conclusions. The first is that processes in the natural environment underpin the permanent presence of renewable resources on Earth. Drastic degradation of these processes means impaired access to resources, but may also denote destabilisation of the Earth system, and thus the disappearance of conditions favourable to human life.

Secondly, any continuation of the present rate of degradation of renewable resources has to engender convictions that the risk of exhaustion is actually greater than in the case of the non-renewables. It might be thought that the moment of arrival of such a problem can be compared with the imposition of limits on access to rare earth elements. In the case of the latter, authors are of the view that a crisis situation will arise around 2030.

Thirdly, it is very probable that threats to the environment will not appear in either an abrupt or universal manner. Rather, we may expect a series of local or regional phenomena to emerge, that will nevertheless have tangible social consequences. It is only as society reacts to shortages of defined resources that a cause of dramatic revolutionary change leading to catastrophe may make its appearance. The change in question might involve the administrative system, migration, fighting, revolution or even war over resources. Such cases are not unknown even in our present times, but the scale of them is sure to increase steadily. On the other hand, it will only be as a secondary impact that we may encounter serious, large-scale shortages of the resources people need.

CONCLUSIONS

The above solutions and conclusions give rise to the following general points:

- As environmental factors can shape the future significantly, they should not be marginalised in scenarios for development;
- Limited access to resources or worsening living conditions in a given area may prove to be a significant factor underpinning movements in society that combine with problems occurring on an ever-wider scale to destabilise currently-existing political balances around the world;
- Environmental problems should be addressed in an integrated manner, i.e. with account taken of the influence processes exert on the homeostasis of the Earth and access to resources. The example of climate change makes it clear how interlinked these issues are;
- Renewable resources and associated natural processes would seem to be of greatest significance when it comes to a real risk of a global civilisational catastrophe of environmental origin arising. This is particularly true of problems associated with water (be these related to shortage, pollution or impaired access);

- Assessed as the most limited risk is the widespread occurrence of limitations on access to energy resources. While access to energy represents one of the key conditions if human civilisation is to prove persistent, it would not seem to be threatened (on a global scale) through to the end of the period under consideration at least.

From all of this it must be assumed that environmental threats are capable of bringing about a permanent and major "remodelling" of conditions for life on Earth. And there is a high probability that at least some of the changes anticipated will assume catastrophic proportions. Over a long time perspective at least, that also denotes environmental factors playing their part in changing the configuration of political forces around the world, with the result for many regions being a rapid (and revolutionary) deterioration in living conditions. The pressure societies are then likely to exert may lead to a destabilisation of economic, political and social relations worldwide. A foretaste of this is already tangible in Europe, in the form of the migration crisis. The appearance globally of disturbances relating to resource access, or arising out of disturbances to the natural balance as certain processes peter out, may give rise to problems on a far larger scale than we see at present. It is thus easy to imagine the tensions and emotions associated with any processes by which people adjust to the new situation. History teaches that periods of change, and of the building of new balances of power, always see the elite gaining most from an existing setup resisting change, with uncertainty as to the future then abounding, as well as chaos when and where attempts to adapt are made. Often these are induced by lack of knowledge, as well as the absence of consent or a mandate for changes of direction made. The other possibility is of course a lack of the necessary courage to take decisions that are crucial, but also unpopular. In these circumstances, even minor environmental changes can serve as factors generating serious global catastrophes whose result is – quite literally – the end of civilisation as we know it.

In consequence, the ways in which we consider the future should be far more integrated than they have been, so that account may be taken of environmental elements most delicate and sensitive where planetarily-imposed limits on development are concerned. That said, it is worth recalling that the environment and the changes ongoing in it should not – may not – be analysed in isolation from human activity. By way of the economy and culture, societies can exert a major influence in shaping local and regional ecosystems – to the extent that they are simultaneously perpetrators and victims of environmental crises. Beyond that, it is worth nothing the great complexity that always characterises environmental issues, as well as the multiplicity of interactions that pertain between the different ones. These ensure that estimates of the potential effects of defined actions taken in the natural environment are always burdened by pronounced risk of error. This remark of course applies to the considerations presented here, despite the authors' considerable efforts to present the problem as reliably as they can.

REFERENCES

Begon M., Harper J. L., Townsend C. R., 1996, *Ecology. Individuals, Populations and Communities*, Blackwell.

Begon M., Mortimer M., 1999, *Ekologia populacji. Studium porównawcze zwierząt i roślin* (*Population ecology. A unified study of animals and plants*), PWN, Warsaw.

Béné C., Arthur R., Norbury H., Allison E. H., Beveridge M., Bush S., Williams M., 2016, *Contribution of Fisheries and Aquaculture to Food Security and Poverty Reduction: Assessing the Current Evidence*, World Development, *79*, 177–196, http://doi.org/10.1016/j.worlddev.2015.11.007.

Buks J., Prandecki K., 2015, *Usługi środowiska w rolnictwie*, (*Environmental services in agriculture*), Europa Regionum, XXI, 127–137, http://doi.org/DOI: 10.18276/er.2015.21-11.

Colinvaux P., 1993, *Ecology 2*, John Wiley & Sons, Inc., New York.

Convention on Biological Diversity, 1992, Rio de Janeiro, June 5th 1992.

Cotgreave P., Forseth, I., 2002, *Introductory ecology*, Blackwell.

Cowie J., 2009, *Zmiany klimatyczne. Przyczyny, przebieg i skutki dla człowieka*, (*Climate Change. Biological and Human Aspects*), Wydawnictwa Uniwersytetu Warszawskiego, Warsaw.

Ercin A. E., Hoekstra A. Y., 2014, *Water footprint scenarios for 2050: A global analysis*, Environment International, 64, 71–82, http://doi.org/10.1016/j.envint.2013.11.019.

Gerten D., Rockström J., Heinke J., Steffen W., Richardson K., Cornell S., 2015, *Response to Comment on "Planetary boundaries: Guiding human development on a changing planet*", Science, *348* (6240), 1217–1217, http://doi.org/10.1126/science.aab0031.

Gruszczyński S., 2014, *Zmiany w środowisku glebowym i ich skutki*, (*Changes in the soil environment and their consequences*), Przyszłość Świat-Europa-Polska, 2/30, 36–64.

IPCC, 2013, *Climate Change 2013 The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, New York.

Jaramillo F., Destouni, G., 2015, *Comment on "Planetary boundaries: Guiding human development on a changing planet"*, Science, 348 (6240), 1217–1217, http://doi.org/10.1126/science.aaa9629.

Kleer J., 2012, *Zagrożenia globalne: próba identyfikacji* (*Global threats: an attempt to identify*), Przyszłość Świat-Europa-Polska, 2/ 26, 14–29.

Kleer J., Kleiber M., 2015, *Zagrożenia globalne barierami rozwoju* (*Global Threats as barriers to development*), Polska Akademia Nauk Komitet Prognoz "Polska 2000 Plus", Warsaw.

Klein A. M., Vaissière B. E., Cane J. H., Steffan-Dewenter I., Cunningham S. A., Kremen C., Tscharntke T., 2007, *Importance of pollinators in changing landscapes for world crops*, Proceedings of the Royal Society of London B: Biological Sciences, 274 (1608), 303–313, http://doi.org/10.1098/rspb.2006.3721.

Krebs C. J., 1996, *Ekologia. Eksperymentalna analiza rozmieszczenia i liczebności*, (*Ecology. The Experimental Analysis of Distribution and Abundance*), PWN, Warsaw.

Lean G., 2009, *Water scarcity now bigger threat than financial crisis*, The Independent (15 March).

Łomnicki A., 1988, *Population ecology of individuals*, Princeton Univ. Press, Princeton.

MacArthur R. H., Connel J. H., 1971, *Biologia populacji* (*The Biology of Populations*), PWRiL, Warsaw.

Majewski J., 2014, *Economic Value of Pollination of Major Crops in Poland*, Economic Science for Rural Development, 34, 14–21.

Michałowski A., 2011, *Ekonomiczne podstawy usług środowiska* (*The economicbasis of ecosystem services*), Optimum Studia Ekonomiczne, 6 (54), 105–120.

Michałowski A., 2012, *Efektywność gospodarowania w świetle usług środowiska* (*Efficiency of management in the light of ecosystem services*), Optimum Studia Ekonomiczne, 1 (55), 99–118.

Michałowski A., 2013, *Usługi środowiska w badaniach ekonomiczno-ekologicznych* (*Ecosystem services in economic and ecological research*), Ekonomia i Środowisko, 1 (44), 29–51.

Michałowski A., 2014, *Ochrona przyrodniczych procesów usług środowiska w perspektywie ekonomii zrównoważonego rozwoju* (*Protection of the natural processes of environmental services in the perspective of sustainable development economics*), Przyszłość. Świat – Europa – Polska, 2 (30), 121–140.

Michałowski A., 2015, *Usługi środowiska w świetle bezpieczeństwa ekologicznego* (*Ecosystem services in the light of ecological security*), Ekonomia i Środowisko, 4 (55), 10–24.

Odum E. P., 1977, *Podstawy ekologii* (*Fundamentals of Ecology*), PWRiL, Warsaw.

Petersen R., Sizer N., Hansen M., Potapov P., Thau D., 2015, *Satellites Uncover 5 Surprising Hotspots for Tree Cover Loss « Global Forest Watch*, http://blog.globalforestwatch.org/2015/09/2014-tree-cover-loss-2/ (September 1, 2016).

Petersen R., Goldman L., Weisse M., Aksenov D., 2016, *Forest Loss Pushes Far Beyond Plantation Boundaries in South America, Africa*, http://blog.globalforestwatch.org/2016/01/forest-loss--pushes-far-beyond-plantation-boundaries-in-south-america-africa/ (January 25, 2016).

Prandecki K., 2013, *Wyzwania globalne* (*Global challenges*), [in:] *Perspektywy nowego ładu światowego*, Oficyna Wydawniczo-Poligraficzna "Adam", Warszawa, 95–131.

Prandecki K., 2014a, *Agriculture and climate change*, [in:] *The new EU agricultural policy – continuation or revolution?*, Institute of Agricultural and Food Economics – National Research Institute, Warsaw, 130–140.

Prandecki K., 2014b, *Perspektywy ograniczenia konsumpcji zasobów naturalnych do 2050 r.* (*The perspectives to reduce the consumption of natural resources by 2050*), [in:] *Czy kryzys światowych zasobów?*, Polska Akademia Nauk Komitet Prognoz "Polska 2000 Plus", Warsaw, 137–163.

Prandecki K., Michałowski A., 2016, *Środowiskowe ryzyko katastrofy rozwoju cywilizacyjnego* (*Environmental risk of civilizational development catastrophe*), *Przyszłość. Świat – Europa – Polska*, 2/34, 24–58.

Prandecki K., Gajos E., Buks J., 2015, *Z badań nad rolnictwem społecznie zrównoważonym [32] Efekty zewnętrzne i dobra wspólne w rolnictwie – identyfikacja problemu*, (*From the research on socially-sustainable agriculture [32] External effects and common goods in agriculture – problem identification*), Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej Państwowy Instytut Badawczy, Warszawa.

Prandecki K., Sadowski M., 2010, *Międzynarodowa ewolucja ochrony środowiska* (*The international evolution of environment al protection*), LAM – Wydawnictwo Akademii Finansów, Warszawa.

Prandecki K., Wrzaszcz W., Buks J., Bocian M., 2014, *Z badań nad rolnictwem społecznie zrównoważonym [25] Produktywność wybranych form rolnictwa zrównoważonego* (*From the research on socially-sustainable agriculture [25] Productivity of selected forms of sustainable agriculture*), K. Prandecki (ed.), Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej Państwowy Instytut Badawczy, Warsaw.

Randers J., 2012, *2052 A Global Forecast for the Next Forty Years*, White River Junction, Vt: Chelsea Green Publishing.

Remmert H., 1985, *Ekologia* (*Ecology*), PWRiL, Warsaw.

Richling A., Solon J., 2011, *Ekologia krajobrazu* (*Landscape Ecology*), PWN, Warsaw.

Ricklefs R. E., 1990, *Ecology*, Freeman, New York.

RT, 2013, *Water scarcity by 2030: True for every second person on earth*, UN says [RT, August 10], Downloaded 16 October 2013, athttp://rt.com/news/water-shortage-un-population-901/.

Springmann M., Mason-D'Croz D., Robinson S., Garnett T., Godfray H. C. J., Gollin D., … Scarborough P., 2016, *Global and regional health effects of future food production under climate change: a modelling study*, The Lancet, http://doi.org/10.1016/S0140-6736 (15)01156-3.

Stern N., 2006, *The Economics of Climate Change (The Stern Review)*, Cambridge University Press, Cambridge.

Townsend C. R., Begon M., Harper J. L., 2003, *Essential of Ecology*, Blackwell.

Uchmański J., 1992, *Klasyczna ekologia matematyczna* (*Classic Mathematical Ecology*), PWN, Warsaw.

UN Water, 2015, *Water and Sustainable Development. From Vision to Action*, UN Water Decade Programme, Zaragoza.

Weiner J., 2015, *Życie i ewolucja biosfery. Podręcznik ekologii ogólnej* (*Life and Evolution of the Biosphere. General Ecology Guide*), PWN, Warsaw.

WHO, 2015, *Key Facts from JMP 2015 Report*, WHO/UNICEF Joint Monitoring Programme, http://www.who.int/water_sanitation_health/publications/JMP-2015-keyfacts-en-rev.pdf?ua=1.

Wijkman A., Rockström J., 2012, *Bankrupting nature: Denying our planetary boundaries*, Routledge, London.

WWAP, 2015, *The United Nations World Water Development Report 2015: Water for a Sustainable World*, UNESCO, Paris.

WWF, 2014, *Living Planet Report 2014: Summary*, WWF, Gland.