GEOGRAFIE – SBORNÍK ČESKÉ GEOGRAFICKÉ SPOLEČNOSTI
ROK 2008 ● ČÍSLO 3 ● ROČNÍK 113

MARTIN BALEJ, JIŘÍ ANDĚL, TOMÁŠ ORŠULÁK, PAVEL RAŠKA

# DEVELOPMENT OF ENVIRONMENTAL STRESS IN THE NORTHWESTERN PART OF CZECHIA: NEW APPROACHES AND METHODS

M. Balej, J. Anděl, T. Oršulák, P. Raška: *Development of environmental stress in the northwestern part of Czechia: new approaches and methods.* – Geografie–Sborník ČGS, 113, 3, pp. xxxxxx (2008). This article deals with the theoretical background to environmental stress theory that includes a multivariables system of indicators and the application of such theory. The environmental stress lies at the intersection of the stressors in the subsystems of a landscape, that is: natural (e.g. relief topography, air, water, soil, and biota) and/or social (e.g. demographic and economic variables). The methodological concept used can be applied to other areas of study because of its broader spatial and functional applications. In comparison to other methodologies used to evaluate the anthropopressures on the landscape (those that monitor changes in land use), the environmental stress assessment is directed at locating 'stressors' beyond the study areas that can significantly impact on future studies.
KEY WORDS: environmental – stress – cultural landscape – northwestern Czechia.

The work was supported by Ministry of Labour and Social Affairs (Czech Republic) through grant Methodical procedure of social and ecological links assessment with economic transformation: Theory and application, No. 1J 008/04-DP1 and by Grant Agency of the Czech Republic through grant project Formation of Social Structures behind the Changing Cultural Landscape in the Period of Transformation, No. GA403/06/0243.

## Introduction

The term stress often is used to describe medical, psychological, biological and physical conditions. It denotes a 'system of power' that causes strain or even produces deformity that damages the 'host' system. The factors producing 'stress' are referred to as: a stressor. For Míchal (1992) such 'outer disturbing factors' are the direct result of a stressor. Stress is the affect or influence of a stressor on a particular system. In the case of a landscape, the system consists of biotic, abiotic and human elements, and 'stress' represents all the deformities that exist in a system. Every impulse that exceeds standard levels of intensity within a system (whether physiological, natural, generally social or economic) is called: stress (or pressure, strain, disturbing force, trouble, and difficulty). It represents an extraordinarily powerful even intensive phenomenon resulting in a series of deviations from common fluctuations. Reactions to stress include resistance (effective) or the opposite – inertia. The ability to react to 'stress' is related to the ability to compensate (remove) the effects. The first phase of the reaction to stress stems from the

principle of resilience. Resistance in this case is interpreted as successful. However, in the final phase a system either collapses (changes its character) or is neutralized by the stress and continues to function. The 'stress' can be thus set off wholly, incompletely or if the 'stress' is not compensated for at all, the system will collapse. Ingegnoli (2002) also argues that if the source of the stress is constant (chronic) or even too strong, this will lead to what is termed: endangering the 'health' of a landscape.

The theory of landscape ecological stressors was developed in Slovakia (Šúriová, Izakovičová 1995; Atlas krajiny Slovenskej republiky 2002). Others, Lipský (1998), Erickson (1999), Antrop (2000), or Ingegnoli (2002) also use the terms environmental stressor, anthropopressure or landscape strain to describe forms of degradation of the natural landscape, natural conditions otherwise seen as: landscape pathology or anthropogenic disturbances.

The identification of such anthropogenic stressors and accounting for these through the concept of 'stress' reveals humans' influences in/on the landscape. The advantage of using terms like 'stress' and 'stressor' helps in identifying the causes as well as the consequences of such environmental effects. Stress is used to describe a meaning broader than its usual context. It covers both 'stress' in the natural and the human landscape subsystems. We can talk about it in connection with all landscape components (natural and human). Stressors also include disturbances, but not only these. Included too are the transformations of land use through anthropogenic activities or noise, odour et cetera. Stress in the human subsystem (e.g. social pathological phenomena, delinquency, unemployment, divorce rate, the rate of natives) and its consequences on the landscape character, landscape structure, and landscape ecological processes, very often remain unnoticed although it is a significant force to "landscape" a system (Hobbs 1997, Risser 1999). Efforts have been made to also quantify the rate of anthropopressure through a ratio that includes land use types (Skowronek et al. 2005). But these are partial views that reflect only certain given environmental issue. The environmental stress assessment can be one of the most suitable methodological concepts to ascertain landscape development trajectories (cf. Conway, Lathrop 2005; Pauleit, Ennos, Golding 2005).

In our research we asked the following questions:

- How will ecological and social stress evolve in different landscape types and at various time periods?
- Is it possible to integrate social and ecological stress into a comprehensive indicator to predict what the complex/negative effects of humans are on landscape subsystems?
- Can the changes in ecological and human stresses be related to each other?
- If so, which has the greater dynamics?
- What are the reasons for the most striking way in which changes in the intensity of stressors can be noted as well as in the subsequent occurrence of stress?
- Where are we to look for the main driving forces?
- What connections are there between individual partial variables?

## Case study: the northwestern part of Czechia

The research includes the three studies conducted alongside the Czech–German borderland (the northwestern part of Czechia) where the

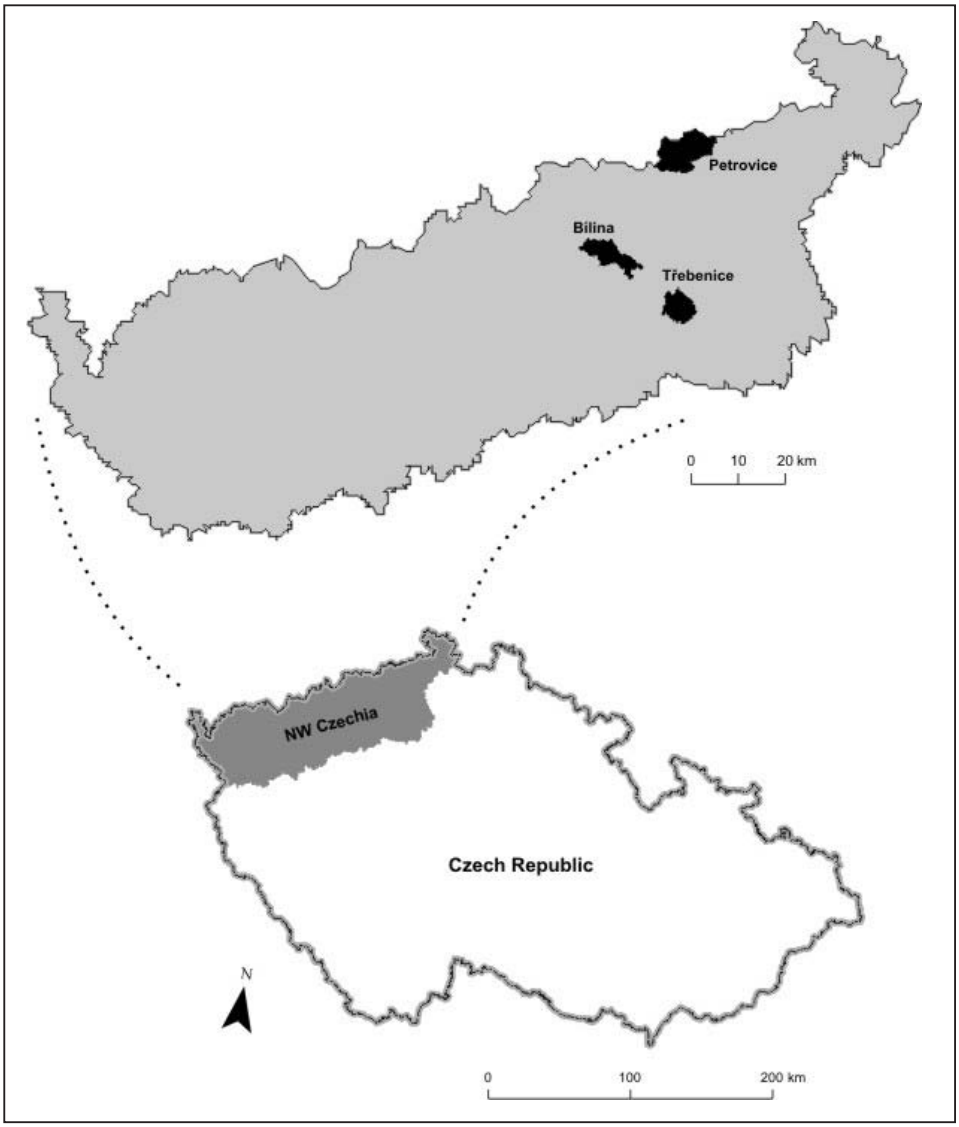


Fig. 1 – Study areas Bílina, Petrovice and Třebenice and their surroundings within the northwestern part of Czechia.

areas are marked by partially different development, mainly induced by different geographical conditions, and then these were analyze in terms of land use and environmental stress changes from the mid 20th century (Fig. 1).

The northwestern part of Czechia was in the past a "barometer" to measure fundamental changes in the development of the Czech landscape. The changes were mostly brought about by industrialization and urbanization processes causing ecological problems as far back as the Saxon towns of the mid 19th century. In the 1950s the environmental stresses increased and by

the 1980s (30 years later) this former region known as Czechoslovakia was in need of critical interventions. At this stage all the natural components of the landscape system were damaged. This high environmental stress now also is visible in the health and demographical variables of the population.

The study area where the environmental stress has the highest intensity is represented by the Bílina area. This study includes the town of Bílina and wider still, also the destroyed settlements. The second, slightly different type of area is more hilly, the border area of Petrovice that lies northwest of the city Ústí nad Labem. The Petrovice area is mountainous, the areas of the Ore Mountains (Krušné hory) significant for its dynamic development until the end of the 19th century. Its subsequent stagnation – both economic and demographical development – further more after World War II resulted in markedly regressive trends that have changed not only the function but the character of the landscape. The third study area is Třebenice where the indications are that this is an intensively agriculturally exploited landscape. Here the landscape function remained stable during its whole development. The Bílina, Petrovice and Třebenice areas are different analogical landscape types in the northwestern part of Czechia.

## Environmental stress: methodological concept

The negative influence on the landscape, i. e. of the changes of the environmental stressors that cause ecological or social stress in the landscape, generally can be grouped according to different characteristic periods of human history (Agnew, Livingstone, Rogers 1996). We can distinguish three basic evolution phases in the development of societies (Hampl 1998):

– The pre-industrial period characterized and determined by natural subsystem, the distribution of settlement structures and economic activities.
– The industrial society marked by the development of a secondary sector that has distinct dynamics of change. Ecological determinations gradually are overcome and the role of socio-geographical factors increase (Berry 1973; Broek, Webb 1978). In our case, this phase is represented by the so-called totalitarian period (the German occupation and the period of communism) which actually represents the final phase of the industrial society and a decline from the natural trajectory of Western Europe (here certain features of a post-industrial society are already revealed). For the northwestern part of Czechia this period means a break in the existing continuity of development.
– The post-industrial society in the Czechia is characterized by an intensive development of communication and information contacts (pressure on transport and communication networks) and by developing tertiary economic sectors such as services and tourism. In the settlement structure there appears to be an integration of all systems. Also, trends focus on depopulating developmental tendencies in large cores ("gravity centers, nodes") in the place of areas in their background (Hampl et al. 2001).

We will focus on the last period of the industrial society in Czechia, i. e. on the totalitarian period, and on the post-industrial phase, where the essential changes of the ecological and social stress development in the study areas can be documented.

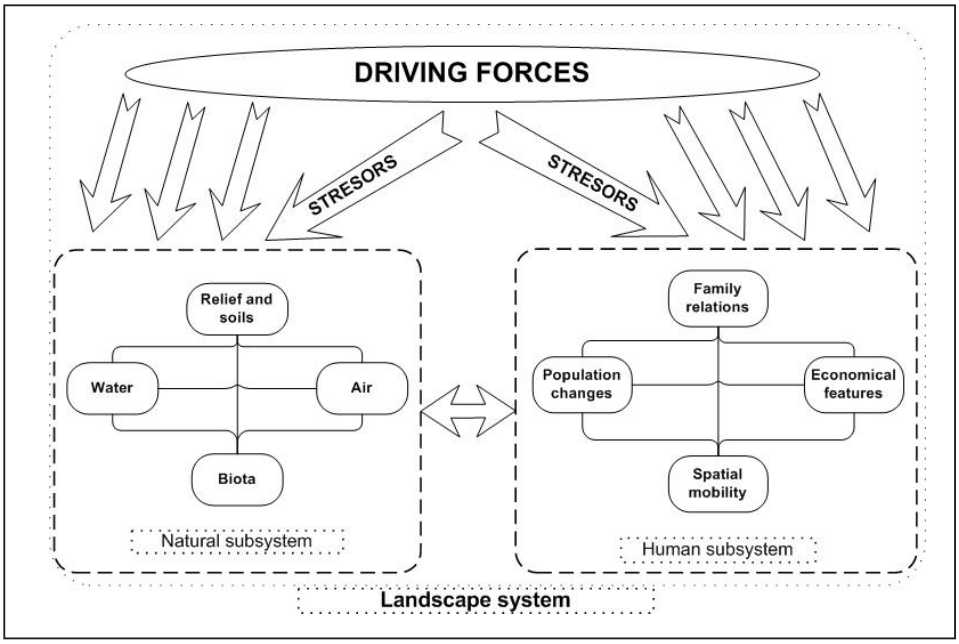


Fig. 2 – The general scheme of the stressor influences and stress occurrence in the landscape system

Marsh, Grossa (2004) consider the presence of the excessive environmental stress level in the landscape system to be the basic factor distinctively determining the so-called environmental quality. The environmental quality, as a fundamental attribute of the landscape system, is threatened by synergic influences of environmental stressors on both natural and human subsystems (Fig. 2).

In the methodical procedure of the ecological and social stress accounting we divide the period of the second half of the 20th century (totalitarian and post-industrial period) into five time horizons for which there are valid databases available. Approximately in 1950 the final stage of the industrial period begins. In the totalitarian period environmental stressors start to intensify dramatically. The two following time horizons (1970 and 1980) indicate dynamic changes in the totalitarian era. This ends in the year 1990 when the post-industrial period arrives. The last horizon – 2005 – documents the phase of inhibition of stressors in the post-industrial period.

The focus of the article is to obtain our own methodology to assess the environmental stress and the latter's application in specific geographical conditions. The methodology of evaluating the ecological and social environmental load developed by The Research Institute of Constructing and Architecture (VÚVA) in Prague in 1991, becomes an accounting system for ecological load evaluation as well as experimental and social load evaluation (Anděl 1993). The VÚVA methodological concept was applied to the whole territory of Czechia in 1991. Comparative studies in development after 1989 used identical parameters to measure conditions in eight study areas in the Ústí nad Labem region in 2001 (Balej 2004).

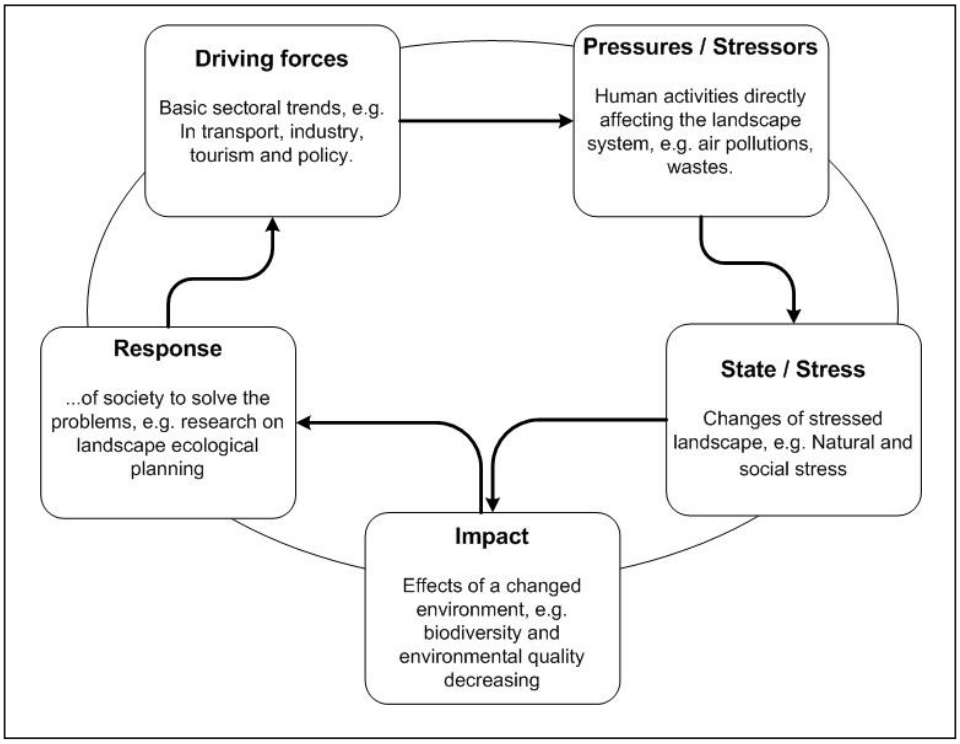


Fig. 3 – The DPSIR scheme "Driving forces – Pressures – State – Impact – Response". Source: Jesinghaus (1999).

The environmental stress in the study area indicates the influence of the stressors that are located both within the area and also in areas beyond its borders. The effects of environmental stressors don't respect administrative boundaries. From the terminological reference the stress follows internationally recognized methodological schemes evolved on the basis of the EEA concept (European Environmental Agency; Jesinghaus 1999). Environmental stress accounting reflects the anthropogenic pressures in the DPSIR scheme ("Driving forces – Pressures – State – Impact – Response", Fig. 3).

A fundamental point of the methodological procedure is to choose the indicators and then to represent these according to their particular features in the natural and human subsystems (Anděl 1993). The accounting process is done in correspondence with similar methods that are based on a set of rating points. The maximum interval of the chosen indicator for a monitored area then is divided into quartiles. Values are assigned to each as follows: in the range of low (quartiles Q1=0), below the average (Q2=1), above-average (Q3=2) and high (Q4=3). These then are multiplied by relevant weights (e. g. 1 or 2). Naturally the hierarchy level is important. In the environmental stress accounting, the variation interval for individual indicators with hierarchy level increases and there can even be different scale of rating points. The following environmental stress assessment is valid for any other territory.

For the purpose of the ecological stress accounting (EcoS) we first notice the degree of degradation of the relief and soils (Tab. 1). For the northwestern part of Czechia a distinctive anthropogenic topography transformation is typical

Tab. 1 – Ecological stress indices

| | | | | |
|---|---|---|---|---|
| Group | Index | Indicator | Specification | Weight* |
| Relief and soils degradation | $A_1$ | Degree of anthropogenic transformation | Presence of anthropogenic landforms in | 2 |
| | $A_2$ | Potential aeolian and water erosion | Degree | 1 |
| | $A_3$ | Dumping places | Degree | 2 |
| Air pollution | $A_4$ | Air pollution $SO_2$, $NO_x$, air dust | $\mu g.m^{-3}$ | 2 |
| | $A_5$ | Local sources of air pollution | $t.km^{-2}$ | 1 |
| | $A_6$ | Noise and emission | intensity and frequency of traffic | 2 |
| Water quality | $A_7$ | Surface water course quality | quality factor | 2 |
| Biota | $A_8$ | Forestal air pollution zones | prevailing category A – F | 1 |
| | $A_9$ | Ecological stability index | ratio of relatively stable and unstable land | 1 |
| | $A_{10}$ | Barriers | length of artificial- | 2 |

Note: *according to the assessment made by team of international experts

(e. g. the surface mining of brown coal and quarries for building stone – trachytes and phonolites). These have consequences not only the functional disturbances of the natural subsystem but also in terms of the devaluation of the total visual landscape's quality (Balej 2004). The presence of illegal and controlled dumping land-fills was evaluated by using a 0–3 rating scale. The potential of water and wind soil erosion was calculated by means of the Universal Soil Loss Equation (USLE) as defined by Wischmeier, Smith (1978). Air quality was monitored on the basis of emission concentrations of solid materials, SO2 and NOx and also by the indicator of the air pollution from local sources (namely from houses heated by solid energy sources). The surface water quality is represented by the indicator of the quality of the water in streams. Ecological stress in the vegetation cover reflects of emission zones of forest areas (the proportion of forest areas with deteriorated health state, that is: the defoliation of treetops measured in %), and the ecological stability index according to Míchal (1992) (ratio of ecologically relatively stable and labile land use types). With respect to the completeness of the information about the stress in the natural subsystem the barrier effect calculation and the presence of noise or odour cannot be omitted. The landscape fragmentation first of all by transportation barriers (Anděl et al 2005) was calculated as the density of transportation lines (railway and roads) with individual stages being moreover weighted by the intensity of traffic (by the number of vehicles or trains passing on them within 24 hours). The ecological stress (EcoS) is given by
where $w$ stands for the weight (1 or 2), $n$ indicates the number of indicators 1 till 10 and $An$ is the indicator of ecological stress.

$$EcoS = \sum_{n=1}^{10} w * A_n$$

Tab. 2 – Social stress indices

| Group | Index | Indicator | Specification | Weight* |
|---|---|---|---|---|
| Population change | $B_1$<br>$B_2$<br>$B_3$ | Natality<br>Natural increase<br>Index of vitality | 5 years average<br>5 years average<br>preproductive / postproductive | 1<br>1<br>2 |
| Family relation | $B_4$<br>$B_5$ | Divorce rate<br>Incomplete families | 5 years average<br>number | 1<br>2 |
| Economic relation | $B_6$<br>$B_7$ | Index of education<br>Unemployment | university / elementary<br>5 years average | 2<br>2 |
| Spatial relation | $B_8$<br>$B_9$<br>$B_{10}$ | Natives<br>Migrational balance<br>Migrational change | in %<br>5 years average<br>5 years average | 2<br>2<br>1 |

Note: *according to the assessment made by team of international experts

Social stress (SocS) reflects social aspects which we consider as having a negative effect on o human beings. A set of evaluating indicators should therefore indicate basic population features (Tab. 2). The population movement is evaluated by three indicators – the vitality index (rate of pre-productive and post-productive component), the level of the birth rate and the natural growth. In the case of the municipality scale of the research it is important to work with the last two mentioned indicators and a five-year of averages to eliminate random phenomena. Family disturbance indicates the rate of incomplete to complete families and we set the divorce rate as the number of divorces per 1,000 inhabitants in the given five-year period. We monitor the economic features with the help of the unemployment rate. As in the totalitarian period it did not exist statistically and it is correct to work with this indicator only in the last time horizon rather than to abstract from it. In the environmental stress methodological concept it nevertheless acts as an indicator which for the territories not having gone through the totalitarian era is not substitutable. An important indicator is the educational structure monitored via the index of education calculated as the proportion of inhabitants with university/college to those with basic education. Indicators monitoring the spatial movement of inhabitants form a distinctive group. They testify implicitly about the relationship of the inhabitants to the territory where they live. One of the indicators is the ratio of inhabitants born in the living place, the second is the migration balance indicating attractiveness or on the contrary unattractiveness of the study areas, and the third is the migration turnover testifying about a labile or stable relation to the living place. Both of the last indicators are, with respect to the possible contingency, monitored in a five-year time horizon (Haggett 1975). The social stress (SocS) is given by

$$SocS = \sum_{n=1}^{10} w * B_n$$

where $w$ is for the weight (1 or 2), $n$ indicates the number of indicators 1 till 10 and $Bn$ is the indicator of social stress.

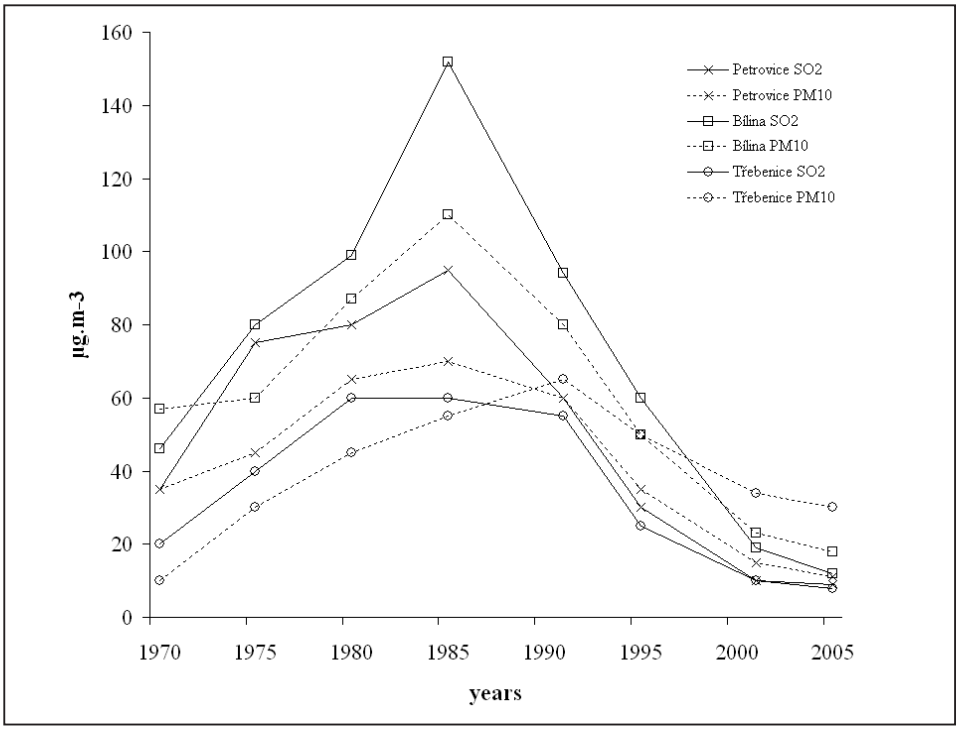


Fig. 4 – Average $SO_2$ and $PM_{10}$ (particles smaller than 10 µm) concentrations in the study areas (µg.m$^{-3}$ per year). Source: data of CHMI.

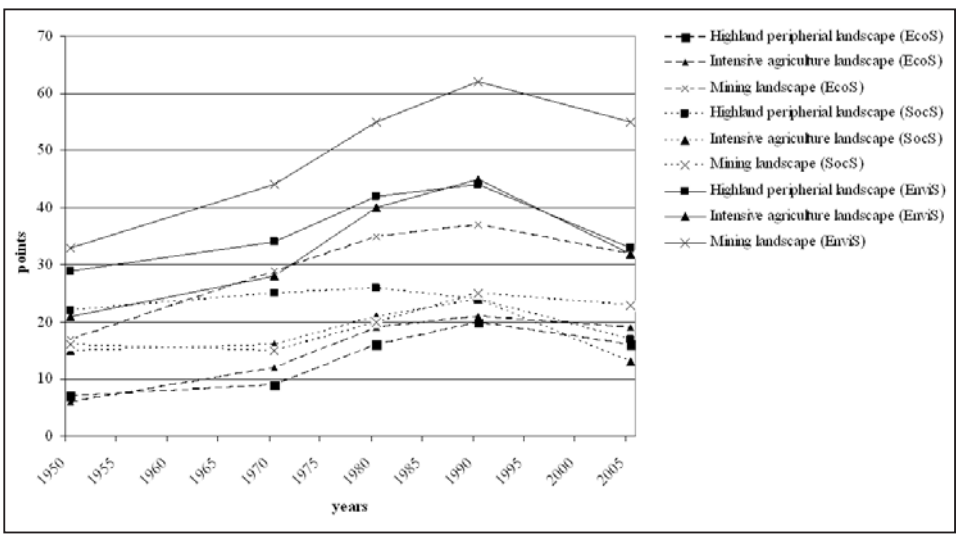


Fig. 5 – The development of the ecological (EcoS), social (SocS) and environmental (EnviS) stresses in the study areas in the period of 1950–2005

## Results

The "strongest" stressing factor, from the point of view of the influences rate on other components of the natural subsystem, are stressors causing 'stress' in the air and which consequently and synergistically have an effect on the whole natural subsystem. Figure 4 shows the development of the A4 indicator, which was changed in the most dynamic way.

The ecological stress development confirms dynamic changes in the impact of the most prominent stressors especially where power stations produce multiplicative stressing effects on landscape components (Fig. 5). The high increase of the ecological stress until 1990 is connected to both air pollution and also the increasing deterioration of forest growth. Also affected are an increase in anthropogenic soil and relief transformation and a decrease in the quality of surface streams. On the other hand, there has been a markedly and even dynamic decrease in ecological stress after 1990 in all the study areas but this is compensated by stressing effects of increased traffic intensity. There also has been the affects of intensified noise and transport emissions, the expanding landscape fragmentation, the non-decreasing degree of the anthropogenic relief and soil transformation and a non-improving state in health of the forest growths. The amplitude of the ecological stress changes has reached, in this second half of the 20th century, its maximum values in Třebenice area (more than 300 %), in Petrovice area (almost 300 %) and in Bílina area (more than 200 %). Among these three study areas Bílina is worse hit in that this area exceeds others as a distinctively impaired natural subsystem. It reaches the highest values in all monitored indicators of the ecological stress.

Environmental stress (EnviS) is the sum of stress in two subsystems (social and natural):

$$EnviS = \sum_{n=1}^{10} w * B_n + \sum_{n=1}^{10} w * A_n$$

where $w$ is the weight (1 or 2), $n$ indicates the number of indicators from 1 till 10 and $An$ and $Bn$ are indicators of ecological and social stress respectively.

While some partial indicators may act in different ways and even include opposite directions (such as registering positive immigration in the social subsystem but negative in relation to the natural one), in general such variability does not pose a significant problem.[1]

The totalitarian period (the German occupation and the period of communism between1939–1990) is a final phase in the Czechia industrial society. For the northwestern part of Czechia this means a break with existing development practices and opening up to a dynamic growth of the ecological and social stresses. This turning point then also is, besides the intensive increase in anthropogenic stressors, connected to strong migration movements. The latter refers to the transfer of Germans to "new" settlements on the borderland. This relocation of the German population here and movement of people from the Czech interior have resulted in changes both quantitative and qualitative in character. The insufficient occupancy for

[1] The relation of indicators in both subsystems has been analysed by correlation coefficients and will be further analysed in a future research.

emigrating population between 1930 and 1950 had resulted in a population deficit for Petrovice area of approx. 72 %, for Bílina area 30 % and for Třebenice area 25 %. Other significant indicators include nationality, age categories and changes in economic development. This new settlement has certain distinguishing albeit negative specifics: a higher ethnic heterogeneity, an unfavorable educational structure and a distinctive social pathology (i. e. delinquencies, drug addiction, steep divorce rates). On the one hand these settlement gravity towns have grown dynamically but on the other there has been a "collapse" of the structure in the smaller settlements. Also there have been a number of settlements that have been abandoned in the post-war non-settlement period, such as the territory of the Czech-German borderland. In Petrovice area two-thirds of the settlements have disappeared. However, because of the brown coal mining in the Bílina area, the town of Bílina still remains as one out of eight settlements. Here new 'in-coming settlers' now live and have lost their historical connections to their landscape. In 1990 the proportion of natives in Petrovice area reached only 25 %. From the aspect of view of migration there are strong labile tendencies (resulting in a high migration turnover). In the totalitarian period a constant high negative migration balance resulted in the younger generations moving into larger towns. This had an effect on the life expectancy index with pronounced family disturbances noted as well as a rise in the number of 'incomplete' families. Throughout the totalitarian period the social stress factors continuously increased to reach a peak towards the end of the period (with gross accelerations in the 1980s).

In the post-industrial period social stress again decreased and regressed to the levels noted at the beginning of totalitarianism (Fig. 5). These changes are apparent from research in the development tendencies of study areas. Here different geographic conditions, the population, social and natural features are brought in. A crucial point in social stress development is then the year 1990. This was when the areas being studied here neared almost identical levels (about 25 points). The social stress in Třebenice and Bílina areas then dramatically accelerated in this second half after a period of stagnation in the first half of the totalitarian period. This was due to decreases in the vitality index, a lowering of the natural growth index and a loss of migration through unattractive migrating prospects. On the contrary, in the Petrovice area the social stress remained very high from the beginning of the totalitarian period; there was a distinctive increase in the first half of the totalitarian period (the loss of the migration through factors of un-attractiveness) after which a phase of stagnation followed. In the post-industrial period the social stress in the areas studied develops in quite different ways. In the Třebenice area there is a decreases due to a positive migration balance and an advancement in natural growth and surprisingly too in the educational structures. In the Petrovice area similar tendencies are evident. Here there is a dynamically expanding rate of natives that guarantees/consolidates the wholes area's social stability. The situation in the Bílina area however is different; here the positive changes of indicators assert themselves with great difficulties.

Correlation analysis showed mutual cohesion of some indicators (e. g. natives or migration balance). It also revealed the existence of negative correlations in cases where groups of social stress were indicated nationwide or within Central European tendencies (e. g. population decline, divorce rate, increasing of the rate of single-parent families). Local specifics are not reflected such as spatial movement or economical relations. This is

Tab. 3 – The present-day typology of the study areas from the point of view of anthropogenic stressors effects and the environmental, ecological and social stresses (1950–2005)

| Indicator<br>Geolocation | Mining–urban<br>regionallyexposed | Recreational<br>semiperiphery | Agricultural<br>periphery |
|---|---|---|---|
| Location<br>(m above sea level)<br>The level of EcoS<br>The level of SocS<br>The level of EnviS | basin<br>(195–215)<br>high<br>high<br>EcoS>SocS<br>Bílina | mountainous<br>(450–750)<br>low<br>relatively low<br>EcoS>SocS<br>Petrovice | lowland<br>(170–260)<br>relatively low<br>Low<br>EcoS=SocS<br>Třebenice |

documented through correlation indexes between groups. Natality, for example, has a high correlation with one-parent families (0.754) and a negative one with the natives ratio (-0.654) and the index of education (-0.717). Inside these groups more or less expected correlations can be found, e.g. natives' ratio and migration balances (0.735). In the frames of the ecological stress it is shown that individual indicators of the ecological stress intensify synergistically (a positive correlation index). Low values of correlation indexes with the group of "biota" indicators document a different character of this component within the natural subsystem. The developmental inertia of qualitative parameters is stronger in this case. Also, dynamics and variability are less intensive.

On the basis of the ecological, social and environmental stresses development, in the combination with the geographic-location factors a very simplified typology can be drawn (Tab. 3): the first type – regionally exposed areas with the prevailing mining and urban functions of the landscape are characterized by a high ecological and social stress, whereas the ecological stress exceeds the social stress significantly; the second type – the semi-periphery with the recreational function – has a low level of stress where social stress dominates over ecological stress. This then can be differentiated from the third type on the periphery that carries an agricultural function and where the ecological and social stresses reach balanced values. The results verify the occurrence of the given types as representatives of larger territorial units of the northwestern part of Czechia. The first type represents polycentric core basin areas under the Ore Mountains with the dominating energy industry and mining function. The second type exemplifies the Ore Mountains plateaus, from the greater part a marginal territory abandoned and after the transfer of the German population permanently under-settled with weakened historical relations to the landscape. The 3rd type is typical for intensively agriculturally managed territory with fertile soils suitable for plant production.

## Discussion and conclusions

Prognoses suggest that by the year 2010 the emission concentrations will decrease to 10 μg m-3. In the next years still a slight decrease can be expected for the ecological stress and then rather stagnation. There may be even a minor increase. In the connection with the presupposed escalation of the electric power output or more precisely opening of heat power station blocks in the next years there can arise possible changes in the concentrations of sulphur dioxide or nitrogen oxides. The growing traffic intensity will

Tab. 4 – Main driving forces in the northwestern part of Czechia

| | Year | Driving forces | EcoS | SocS | EnviS (intensity) |
|---|---|---|---|---|---|
| Totalitarian period | 1945 | transfer of Germans, disruption of historical relations, traditions and customs, break off across-the-border cooperation | high landscape permeability, finely grained mosaic of patches | loss of the relations of man with the landscape | xx |
| | 1948 | central planning, the end of private property, 1st collectivisation wave, depletion of settlement structure, new colonisation | landscape unification – collective openfields | high migration turnover | xxx |
| | 1970 | chemical industry development, 2nd collectivisation wave, development of quarry coal and bulding stone mining | growing air and river pollution | negative migration balance | xxxx |
| | 1980 | development of second dwelling, power engineering, construction of prefab housing estates, dynamical decrease of surface water quality | culmination of air and surface stream pollution, forestdecline, monoculture planting | effort to steady population – "death grant", prefab housing estates | xxxxx |
| Postindustrial period | 1990 | market economy, privatization and restitution, building of sewage processing plants, gasification, rehabilitation of landscape | improvement of air and surface streams quality | lowering of migration turnover, increase of natives | xxxxxx |
| | 2005 | building of transport infrastructure, tourism develoment, suburbanisation and urbanisation trends, reclaiming works, damping of surface mining | noise and traffic emissions, damaged forest growths, anthropogenic dagradation of soil and relief, barriers | positive migration balance, strengthening of identity of man with a landscape | xxx |

definitely contribute to increased toxic levels. The variability of emission concentrations of solid polluting particles in the air, namely in rural areas and during winter months, is dependent on the in which real use of ecologically-more-friendly fuels in households. The air emissions of the polluting agents possess many additional effects on the other components of the natural subsystem. Also insulation intensity is decreased through the higher degree dust particles present in the air (PM10). It has been noted that in topoclimatic conditions the air circulation has declined. The influence of the precipitations acidity on the chemical soil characteristics belongs among the most prominent impacts on other landscape components. Due to the acid rainfalls, the pH factor of soils in the northwestern Czechia has dropped by

an approximate average of 0.5 degree during the 1971–1981. It is hard to anticipate whether there will be improving tendencies within the indicators that relate to anthropogenic soil and relief transformations. It is expected that the health state of the forest growths will stagnate in direct relation to the soil pollution. Also, the global climatic changes will affect the planted spruce tree monocultures in lower locations and these will suffer from more distinctive damage. Increasingly, however, there is a tendency to respond to the intensity of the line stressors. Since the 1980s a twofold (in some cases even more) increase in the carrying capacity of the communications by vehicles has occurred. This increase has an unambiguous stress effect that results in higher landscape fragmentation and also alongside intensified communications and increased traffic. The noise and emissions from the transport will thus increase.

Driving forces are a decisive factor in the environmental stress development (Tab. 4). The determining driving forces in the first phase of the totalitarian period were the transfer of the German population and the following non-settlement. It caused a break of continuity in the landscape trajectory and also the relationship between humans and the landscape. The second phase (after 1948) was distinguished by the abolition of private property, the collectivization and by negative developmental trends in the settlement structure. The environmental stress was increased namely by landscape "unification", homogenization (both of the function and the structure) and by a high migration turnover (lability of settlement). New settlers from the Czech interior were often unsuccessful in "growing together" with their place of living. The question is: Is a landscape a scene we are looking at, or a world we are living in? (Wylie 2007). The third phase of the totalitarian era (after 1970) is distinguished by a high pressure on the natural subsystem (the development of the quarry coal mining, energy and chemical industries). As the ecological stress increases dynamically, this has a consequent effect attached to the loss of the landscape attractiveness. Also, this results in "changing the polarity" balance of the migration to a negative. This tendency culminated in the threat of an ecological disaster in the 80s: the culmination of air and water pollution and, forests in decline etc. The disturbance of the natural subsystem shows itself negatively on the state of health of the population. The emigration of the inhabitants is regulated politically and in the form of so-called stability bonuses commonly known as: "death grants".

The predominant driving forces in the post-industrial period are connected with the market economy and necessarily also with applying ecological disposals. The air quality and water in surface-streams is markedly improving, limits are being placed on coal mining and there is evidence of the landscape being reclaimed. Improvement to the quality of the environment is also attracting tourism which boosts the migration balance from a negative to a positive orientation. Slowly the identity of humankind with the landscape is strengthened.

Between the totalitarian and the post-industrial periods we can find essential changes of the environmental stress development. While the totalitarian era is characterized by the dynamic increase of the ecological stress and by a certain shift ("delay") of the social stress, in the post-industrial period we identify a decrease of the ecological stress and again with a definite shift also of the social stress. This fact together with the twofold higher amplitude of changes in the ecological stress as compared to the social one

thus undoubtedly testifies about a higher dynamic of the natural subsystem and about a higher persistence of the social subsystem. Regarding the indicators used in the research, those proposed by the authors and then refined by the team of international experts, this conclusion indicates taht the higher "vulnerability" of the natural subsystem, the greater the complexity of the social subsystem. Notwithstanding, it has to be mentioned that using another set of indicators (according to data accessibility and relevancy), this conclusion may not be valid generally. An important role is undoubtedly played by a greater merging of social items and where certain negative trends now can be neutralized by opposite tendencies. It is shown that for e.g. air or water quality changes, heading toward a positive development, can be carried out in a relatively shorter time horizon, whereas in the social subsystem changes can be reached only in a relatively long time horizon. Differences surface within individual components of the natural subsystem. It turns out that abiotic elements likewise are subject to developmental changes more quickly than biotic ones. The stress caused by polluted air decreases far more dynamically than the stress induced for e.g. by the deterioration of forest growths or soil acidification. Other argument is the unimproved health of forests in the Ore Mountains even after a rapid decrease of emissions concentrations.

## Reference:

AGNEW, J., LIVINGSTONE, D., ROGERS, A. (1996): Human Geography – an Essential Anthology. Blackwell Publishing, Oxford (reprinted 2003), 696 p.

ANDĚL, J. (1993): Metody hodnocení kvality životního prostředí. Sborník ČGS, 98, No. 1, pp. 25 –33.

ANDĚL, P., GORČICOVÁ, I., HLAVÁČ, V., MIKO, L., ANDĚLOVÁ, H. (2005): Hodnocení fragmentace krajiny dopravou. Agentura ochrany přírody a krajiny ČR, 126 p.

ANTROP, M. (2000): Changing patterns in the urbanized countryside of Western Europe. Landscape Ecol., 15, pp. 257–270.

BALEJ, M. (2004): Ecological stress on a landscape: case study from Eastern Ore Mts. In: Michalczyk, Z.: Badania geograficzne w poznawaniu srodoviska. UMCS, Lublin, pp. 461–469.

BASTIAN, O., STEINHARDT, U. (eds.), (2002): Development and perspectives of landscape ecology. Kluwer Ac. Publish., Dorddrecht, 498 p.

BERRY, B. J. L. (1973): The Human Consequences of Urbanization. St. Martin´s Press, N. York.

BROEK, J. O. M., WEBB, J. W. (1978): A Geography of Mankind. New York, 494 p.

CONWAY, T. M., LATHROP, R. G. (2005): Alternative land use regulations and environmental impacts:assessing future land use in an urbanizing watershed. Landscape and Urban Planning, 71, pp. 1–15.

ERICKSON, D. L. (1999): Rural land use and land cover change. Land Use Pol., 12, pp. 223–236.

HAGGETT, P. (1975): Geography: A Modern Synthesis. N. York, 620 p.

HAMPL, M. a kol. (2001): Regionální vývoj: specifika české transformace, evropská integrace a obecná teorie. PřF UK, Praha, 328 p.

HOBBS, R. (1997): Future landscapes and the future of landscape ecology. Landscape Urban Plan., 37, pp. 1–9.

INGEGNOLI, V. (2002): Landscape ecology: a widening foundation. A holistic unifying approach. Springer-Verlag, New York, 340 p.

JESINGHAUS, J. (1999): A[RTF bookmark start: XMark1][RTF bookmark end: XMark1] European system of environmental pressure indices. First volume of the environmental pressure indices handbook, the indicators. European Commission, 254 p.

Atlas krajiny Slovenskej republiky (2002). Bratislava 2002, MŽP SR, Banská Bystrica: SAŽP, 344 p.

LIPSKÝ, Z. (1998): Krajinná ekologie pro studenty geografických oborů. Karolinum, Praha, 129 p.
MARSH, W. M., GROSSA, J. (2004): Environmental Geography: Science, Land Use, and Earth Systems. John Wiley & Sons, 512 p.
MÍCHAL, I. (1992): Ekologická stabilita. Brno, Veronika, 243 p.
PAULEIT, S., ENNOS, R., GOLDING, Y. (2005): Modeling the environmental impacts of urban land use and land cover change – a study in Merseyside, UK. Landscape and Urban Planning, 71, pp. 295–310.
RISSER, P. G. (1999): Landscape ecology: Does the science only need to change at the margin? In: Klopatek, J. M., Gardner R. H. (eds.): Landscape ecological analysis – Issues and applications. Springer-Verlag, New York, pp. 3–11.
SKOWRONEK, E., KRUKOWSKA, R., SWIECA, A., TUCKI, A. (2005): The evolution of rural landscapes in mid-eastern Poland as exemplified by selected villages. Landscape and Urban Planning, 70, pp. 45–56.
ŠÚRIOVÁ, N., IZAKOVIČOVÁ, Z. (1995): Territorial system of anthropogenic stress factors in landscape ecological planning. Ekológia, 14, No. 2, pp. 181–189.
WYLIE, J. (2007): Landscape. Routledge. 264 p.
WISCHMEIER, W. H., SMITH, D. D. (1978): Predicting rainfall erosion losses. USDA. Agricultural Research Service, Washington, DC, 537 p.

Shrnutí

## VÝVOJ ENVIRONMENTÁLNÍHO STRESU V SEVEROZÁPADNÍ ČÁSTI ČESKA: NOVÉ PŘÍSTUPY A METODY

Článek se věnuje metodice hodnocení krajiny z pohledu environmentální geografie. Zabývá se teoretickým vstupem do problematiky, multikriteriální soustavou reprezentativních indikátorů, které odráží kvalitu jednotlivých složek přírodního a sociálního subsystému. Evnironmentální stres (environmental stress) představuje průnik působení stresorů na systém kulturní krajiny. Lze jej chápat jako reflexi negativního antropogenního vlivu v časoprostorové dimenzi. Samotný proces hodnocení environmentálního stresu vychází z monitorování negativních vlivů na přírodní subsystém krajiny (reliéf, ovzduší, voda, půda, biota) a na humánní (sociální) subsystém krajiny (demografické a ekonomické parametry). Metodiku lze aplikovat na libovolné území i v širších prostorových a funkčních souvislostech. Oproti jiným metodikám, které hodnotí antropogenní tlak na krajinu prostřednictvím zastoupení jednotlivých kategorií využití území, navrhovaný postup umožňuje zachytit i hybné síly případně stresory, ležící mimo studované území, ovšem s výrazným vlivem na jeho charakter či kvalitu.

Na třech modelových územích, které se vyznačují zčásti odlišným vývojem a zejména různými geografickými předpoklady, dokumentujeme změny ve využití území v různých typech krajin severozápadní části česko-německého pohraničí od poloviny 20. století (obr. 1). Důvodů pro volbu zmíněné oblasti bylo několik. Severozápadní Čechy byly v minulosti určitým „barometrem“, který avizoval zásadní změny ve vývoji českých zemí a většinou stanul na čele těchto změn. Ať už se jednalo o proces industrializace a urbanizace, která zde probíhala v těsné vazbě na saská města v polovině 19. století, či otázky spojené s ekologickými problémy. Ekologický stres zesílil v 50. letech minulého století a o 30 let později dosáhl jako v jediném území Česka až kritických hodnot. Zasaženy a poškozeny byly všechny přírodní složky prostředí. Negativní dopad se projevoval a projevuje i dodnes na zdraví a psychice obyvatelstva.

Negativní působení člověka na krajinu, tedy změny v působení antropogenních stresorů vyvolávajících ekologický či sociální stres v krajině, lze obecně časově seskupit do různých charakteristických období lidských dějin. Můžeme rozlišit tři základní vývojové etapy ve vývoji společnosti: preindustriální, industriální (ukončena totalitní fází) a postindustriální.

Ve vývoji stresu sledujeme mezi totalitním a postindustriálním obdobím kardinální změny ve vývoji environmentálního stresu. Zatímco totalitní období se vyznačuje dynamickým nárůstem ekologického stresu a s určitým posunem („opožděním“) i stresu sociálního, v postindustriálním období sledujeme pokles úrovně ekologického stresu a opět s určitým posunem i stresu sociálního. Tato skutečnost spolu s amplitudou změn (ta je u ekologického stresu v porovnáním se sociálním stresem dvojnásobná) nepochybně vypovídá o vyšší dynamice změn ekologického subsystémů a o vyšší setrvačnosti vývojových trendů subsystému

sociálního. Tento fakt, uvažujeme-li indikátory využité v rámci výzkumu, které byly navrženy autory a zpřesněny mezinárodní expertní komisí, může svědčit o vyšší „zranitelnosti" ekologického subsystému a o větší komplexnosti a vývojové složitosti subsytému sociálního. Nepochybně důležitou roli hraje velká propojenost sociálních prvků navzájem, kdy určité negativní trendy mohou být negovány protichůdnými tendencemi. Ukazuje se, že např. u ovzduší či vod lze provést relativně v kratším časovém horizontu změnu směřující k pozitivnímu vývoji, zatímco u sociálního subsystému lze dosáhnout změn až v relativně dlouhém časovém horizontu. Jistá diferenciace je i u jednotlivých elementů ekologického subsystému. Ukazuje se, že rovněž i abiotické prvky podléhají vývojovým změnám rychleji než biotické. Stres způsobený znečištěným ovzduším klesá daleko dynamičtěji, než stres „měřený" např. znehodnocením lesních porostů či půdy. Příkladem je špatný stav lesů v Krušných horách i po razantním poklesu imisních koncentrací.

Obr. 1 – Geografická poloha Bílinska, Petrovicka a Třebenicka v severozápadní části Česka

Obr. 2 – Obecné schéma působení stresorů a výskytu stresu v krajinném systému. V obrázku shora: hybné síly, stresory, přírodní subsystém (reliéf a půdy, ovzduší, biota, vodstvo), sociální subsystém (rodinné vztahy, ekonomické rysy, prostorová mobilita, populační změna), krajinný systém.

Obr. 3 – Schéma DPSIR „Hybné síly – Tlak – Stav – Impakt – Odezva". V obrázku shora: hybné síly (hlavní odvětvové trendy, např. v dopravě, průmyslu, cestovním ruchu a státní správě), tlaky/stresory (lidské aktivity přímo ovlivňující systém krajiny, např. znečištění ovzduší, odpady), stav/stres (změny stresu v krajině, např. přírodní a sociální stres), impakt (efekty změněného prostředí, např. pokles biodiverziy a environmentální kvality), odezva (společnosti k řešení problémů, např. výzkum krajinně ekologického plánování).

Obr. 4 – Průměrné roční koncentrace SO2 and PM10 v modelových územích (µg.m-3).

Obr. 5 – Vývoj ekologického (EcoS), sociálního (SocS) a environmentálního (EnviS) stresu v modelových územích v období 1950–2005. V legendě shora: horská periferní krajina, intenzivní zemědělská krajina, těžební krajina.

*Authors are with Department of Geography, Faculty of Science, J. E. Purkinje University, České mládeže 8, 400 96, Ústí nad Labem, Czechia; e-mail: balej@sci.ujep.cz.*

*Arrived to the editorial board on January 21, 2008*