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Full Length Research Paper

Land use changes and environmental stress accounting (case study from northwestern part of the Czech-German borderland)

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The authors assess the long-term changes in utilisation of the territory (1845 - 2005). They apply a new methodology called environmental stress accounting. They notice qualitative changes in how utilisation of the territory develops. They assess the stress-causing effects on both the natural subsystem (ecological stress) as well as on the social subsystem (social stress). The aggregate result is a methodology measuring environmental stress, as a sum of stress existing in the natural and social subsystem. The methodology can be applied in a randomly chosen territory at various time scales. It reflects the external spatial relations, i.e. relations with localities beyond the model territory, and indicates causal effects (driving forces). Driving forces directly or indirectly affect the structure and function of the landscape and at the same time the landscape can retroactively be one of the impulses for origination and modification of the given driving force. The process of mutual interaction of driving forces and the landscape is monitored in three different landscape types of the Czech-German border area: 1) "mining landscape", 2) "intensive agriculture" and 3) "highland marginal landscape". We analyse changes in the use of the landscape and the trend in environmental stress in four time phases that are mutually differentiated by their specific characteristics. They generally correspond to stages of change in Czech society: pre-industrial, industrial, totalitarian (final phase of the industrial period) and post-industrial period.

Key words: Environmental stress, land use changes, driving forces, Czech-German borderland

INTRODUCTION

The trend in utilisation of the territory, dynamics of changes in the landscapes' structure in connection with the trend in anthropogenic pressure and its impact are very extensive and also socially desired topics (Bastian et al., 2002; Vos and Meekes, 1999; Veihe, 2003). Geographical information systems (GIS) and the availability of multi-data sources currently offer large opportunities in retrospective views of the landscape (Ayad, 2005; Bender et al., 2005a, b; Zerbe, 2003; Mander and Murka, 2003; Kienast, 1993; Palang et al, 2005). These studies, in connection with methodical procedures that reflect the results of changes to individual types of utilisation of the territory in various time periods, uncover a level of sustainability of the co-existence between the natural and social subsystem in the study area (Antrop, 2003, 2005; Bürgi et al., 2004; Cristea et al., 2003; Lörinci and Balázs, 2003; Hietel et al., 2004; Iverson, 1988). Landscape managers and creators, decision makers and regional planning agencies acquire a significant stimulus and valuable information both about the history of the territory and in particular about the optimal version of sustainable utilisation of cultural landscape (Antrop, 2000; Boeckamnn et al., 2003; Nikodemus et al., 2005; Conway and Lathrop, 2005; Jongman, 2002; Wiggering et al., 2003).

Reflections of both aspects of landscape (natural and social subsystems of cultural landscape), analysis of the trend in utilisation of the territory are often completed by prognoses of further direction, called landscape scenarios (Ahern, 1999; Nassauer and Corry, 2004; Lausch, 2003). They are also often capped off by definition of the optimal version from the perspective of sustainable utilisation of the territory and are therefore a prerequisite for

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application "by the decision making sphere, stakeholders and end users" (Boothby, 2000; Brandt et al., 2003; Csorba, 1996). Landscape ecological research oriented in this way is potentially applied research (Balej, 2004). From the nature of the applied sphere for which landscape ecological research is suitable also follows the required great emphasis on visualisation of the results of research aimed at them becoming more comprehensible, readable and simple (Zee, 1998).

In the study area of the Czech-German border area we monitored individual land use trends in the in four time periods and their connections with the changing intensity of ecological and social stress in the naturally social system. The chosen time periods in the Czech Republic were distinguished by differing economic, social and political conditions: pre-industrial (before 1850), industrial (1850 - 1950), totalitarian [communist] (1950 - 1990), and post-industrial periods (from 1990 until today).

Besides the verified standardised methodical procedures for analysis and interpretation of land use changes (Bičík, 1997; Pauleit et al., 2005; Ružička and Miklós, 1982) we have set up and applied in study territories a set of indicators defining ecological and social stress. These procedures have enabled us to find out the mutual connections of changes in attributes and processes characteristic for the social subsystem and their effects in the form of stresses in the ecological subsystem (Berger, 1987).

Case study – Northwestern part of the Czech-German borderland

The Czech-German borderland (Figure 1) was settled up until the mid 20th century predominantly by Germans (over 90% of the overall number of residents). The national border was stable, but the ethnic border between the Czech and German inhabitants often changed. From the 13th century, the proportion of Czechs decreased, the most after the 30 Year War, when population losses were compensated by German-speaking inhabitants. Since that time the orientation of economic, cultural and political ties also changed. They used to be far more intensive with German (Saxon) towns than with towns in the Czech interior (this also was the case after Czechoslovakia came into being in 1918). The border area towns with inhabitants who were primarily Czech Germans were much richer in terms of properties than towns in the interior of Bohemia comprised predominantly of people from the Czech ethnic group. The uniqueness of the Czech-German borderland besides other things is reflected in the different character of the landscape, individual folk creations and architecture. For example the type of cattle kept was also different. In connection with historical development and features of settlement, people occasionally talk of what they call the “Czech-German borderland, the Sudetan landscape model”. A frequented feature of the Czech-German borderland landscape in the 18th and 19th centuries was tens or hundreds of small workshops and factories strongly dispersed territorially, linked to an older tradition of domestic production (cloth, glass, wooden products). Light metalworks in some areas with exceptional conditions grew into strong industrial centres. The landscape was interwoven with a dense network of routes, which usually peaked in high, dominating features (an observatory, lookout post or a guest facility). Tourists used the spatially scattered accommodation of summer houses or family guest houses and there was therefore no concentration into recreational centres, unlike now. The landscape was relatively equally burdened. The dense rail and road network enabled people to travel to work in factories. Roads were distinguished by the number of light architectonic elements (viaducts, little bridges) sensitively embedded into the territory. Watercourses often bordered walking routes. A typical feature was also the utilisation of energy in watercourses (small hydro-electric power plants).

The gradual concentration of inhabitants and economic activities, together with “restructuring” of landscape use (the invoked processes of industrialisation and urbanisation, which intensified in the totalitarian period of 1948 – 1989) led to new requirements being placed on the landscape. It changed from having a prevailing productive function (or residentially productive) to being a multifunctional landscape. There was a gradual creation of larger territorial units in which various functions dominated: core areas (with industrial, mining, residential service functions); transitional areas and peripheral areas with prevailing functions, which disturb the environment less (extensive agriculture with a prevalence of pasture cattle rearing, ecological and water management functions etc.).

The “mining landscape” type, Bílinsko (total area 4600 ha, average height above sea level 200 m), takes up a suitable and exposed location in the “Mostecká pánev” at the regional development axis. The rolling, now practically totally deforested landscape, lies at a height above sea level of around 200 m, and in the northern and eastern part of the territory the topography is distinctly influenced by humans as a result of extensive surface mining activity. The Bílina river flows through the centre of Bílinsko. A historical trading route led along the river. Archaeological remnants document the ancient settlement of the territory where the present-day town of Bíliny is located. In the 10th century there was a Slavic fortification here. The population differentiation is distinguished by extreme polarity and a concentration of residents in one locality. Currently many people are employed in manufacturing (43%), and conversely employment in agriculture is low. Of the 15,900 inhabitants, the proportion that was born there (natives) is 51%.

The “highland marginal landscape” type, Petrovicko (total area 6400 ha, average height above sea level 650 m), after the 2nd World War took on a strongly peripheral position in the eastern part of Krušné hory (Ore mountains). After 1989 and after the opening of the D8 motorway, the international transport route of Praha-Berlín (Prague-Berlin), the geographical location significantly improved. On the plateau, with a high level of forest species alternating with managed meadows, from the east there is a sandstone rocky town (landscape protected area) attractive to tourists. Sources of groundwater are plentiful and are led into the water supply network, which supplies conurbations in the Krušné hory foothills. The low density of settlements corresponds to the extremely low population density (20 residents per km^2). Petrovicko is distinguished by a lower number of "natives" (only 36%), an extremely low proportion of people employed in manufacturing (20%) and a high proportion of houses used mainly for recreational activities (28%). It represents analogical territories in Krušné hory, which are distinguished by dynamic development already in the first stage of industrialisation (in direct connection with the development of Saxon towns), subsequent stagnation of economic and demographic development and after the Second World War distinctly regressive trends and an overall change in the function of the landscape and its characteristics.

The "intensive agriculture landscape" type – Třebenicko (total area 3600 ha, average height above sea level 220m) with a predominantly flat lowland and only lightly forested topography represents a landscape utilised intensively for agriculture, alternating with fields, plantations and small forested yards. From the north, steep slopes of volcanic sedimentary sets of the České Středohoří (Czech Central Mountains) (landscape protected area) encroach onto Třebenicko. The warm and dry climate, together with the potential of fertile black soils, creates a pre-requisite for intensive agricultural use. Třebenicko is distinguished by a larger representation of older people (19.2% of the 3,800 residents are older than 60), an above-average proportion of "natives" within the scope of north-western Bohemia (49%), a higher proportion of employees in agriculture (9%) and a relatively low proportion of employees in manufacturing (25%). A lack of job opportunities in the territory causes a lot of commuting (65% of economically active people).{For comparison, the proportion of people working in agriculture (year 2001) in the Czech Republic was 4.4%, the proportion of economically active people working in manufacturing was 37.7%, those commuting from their residence was 32.9%, percentage of inhabitants over 65 years of age was 13.8%, and the proportion of holiday homes as a share of the total in the Czech Republic was 13.8%)

METHODS

We assess land use changes in four time periods distinguished in the Czech-German borderland by unique features. They generally correspond to stages in society's development (Hampl, 1996, 1998):

- The pre-industrial period was dominated by employment in the primary sector – agriculture (mining of minerals, forestry in mountainous areas) and low dynamics of change. An important role for distribution of inhabitants is played by natural determination. Popu-lation density was relatively uniform and in 1850 study areas show between 75 and 250 inhabitants per km^2. The limited role of towns in the settlement system leads to a low level of hierarchical organi-sation. In comparison with the next stages, the inhabitants are distributed relatively equally and individual settlements have a low size range.
- Industrial society is distinguished by the development of the secondary sector and a distinct change dynamic. Natural determinations are overcome and the role of socio-geographic and economic factors increases. The process of urbanisation becomes more intensified, and it is linked with a large spatial mobility of citizens. This form of urbanisation, indicated as extensive, is formed in the Czech Republic firstly in the Czech-German borderland, which had strong links to Saxon towns. Also, the industrialisation process begins in the Czech Republic in the Czech-German borderland, from which it expands into other parts of the Czech interior. The range of population density increases dynamically, from 60 to 750 inhabitants per km^2 in 1921.
- The totalitarian period (German occupation and communism) represents the final phase of industrial society and a deviation from the natural trajectory of advanced Europe (where certain characteristics of post-industrial society have already been manifested). For the Czech-German borderland this period represents a break in development and an interruption of what had until then been continuous development (Figure 2). It was ushered in by displacement of residents of German nationality, followed by an extensive disruption of the settlement structure, elimination of the housing stock and the elimination of numerous historical and artistic sites. At the same time there was a weakening of the identification of new settlers with the landscape, which was expressed in the elimination of many local habits and traditions. New immigrants were not "at home" here. This only changes with the 2nd generation and particularly with the 3rd generation. Links to Saxon towns were distinctly subdued. In the Krušné hory foothills, large-volume surface mining of brown coal expanded and so did the connected heavy industry (particularly energy and chemicals). Intensive agricultural production is applied in fertile areas. In the settlement structure the asymmetry of the core versus the periphery became more distinct. Differences in population density also deepened, from 5 to 1,000 inhabitants per km^2 in 1980.
- In the post-industrial stage the tertiary sector also primarily expanded. The system became integrated in the settlement structure. Depopulation tendencies manifest themselves for large cores at the expense of areas in their backwaters. Changes to geographic location conditions led to the advancement of areas that used to be peripheral at the border with Germany. For many of them, tourism ("recreational industry") represents the main carrier of economic and social rehabilitation for the territory (e.g. Petrovicko).

Each of the observed periods is generally ended by the time period to which land use details and data from Census are available – 1845 (or 1850), 1948 (or 1950), 1990, (or 1991) and 2000 (or 2001). Assessment of changes to the landscape functions as a key factor for subsequent land use changes require adequate data and a methodological basis. There is not a lot of data on long-term land use changes, especially for a period longer than a century. The Czech Republic has such a database available thanks to the cadastral mapping carried out in 1826-1843, and in later years these data were linked with continuous records of utilisation of the territory, which is today administrated by the Czech Cadastra l Authority. These data can be used both from maps (1:2880), as well as from a deduced statistical calculation of the area of indivi-

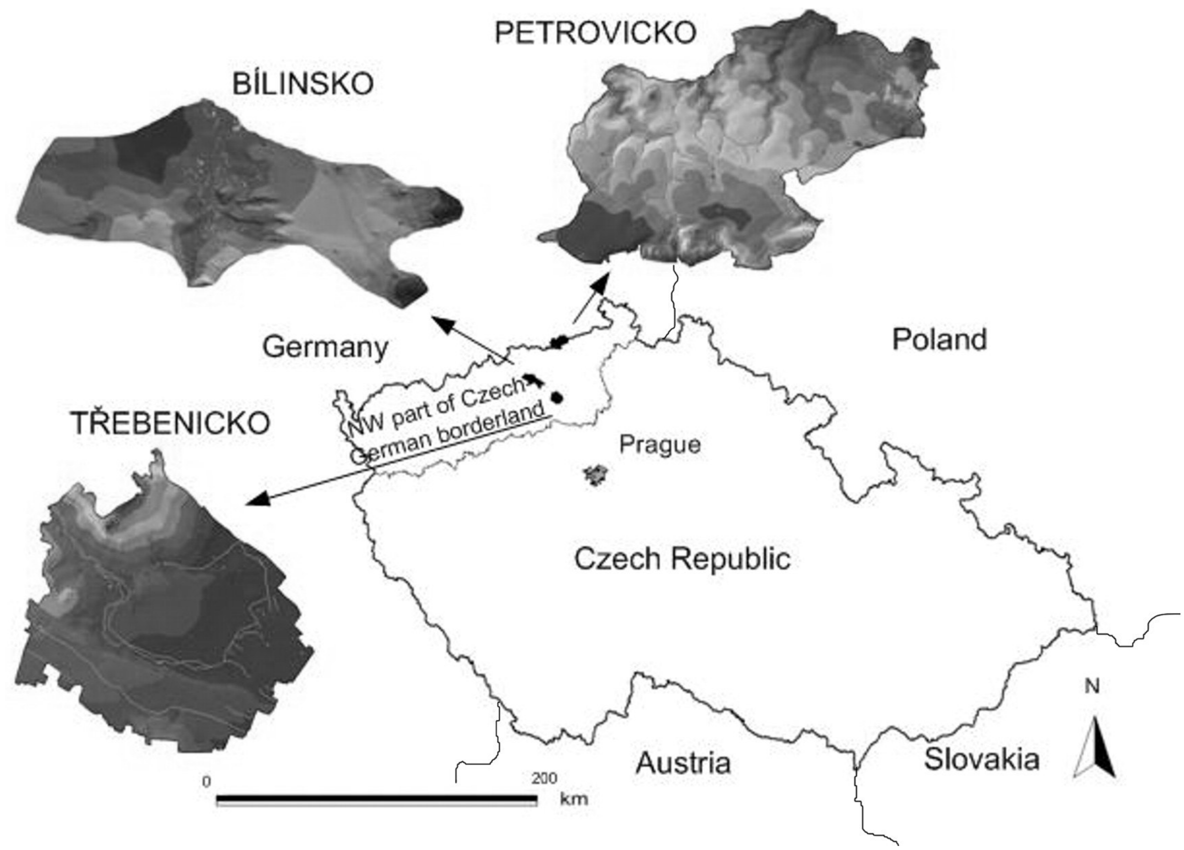

Figure 1. Study areas Bilinsko, Petrovicko and Trebenicko within the Northwestern part of the Czech-German borderland.

dual observed categories. Classes of land use were monitored: forests, meadows, pastures, arable land, permanent cultures, water areas, built-up space, and other space (e.g. logging areas).

We assess ecological and social stress in the period of the second half of the 20th century in five time periods for which credible background data is available. Approximately in 1950 the final section of the industrial period began. It was the totalitarian period, when anthropogenic stress factors began to distinctly intensify. The two subsequent time periods (1970 and 1980) identify dynamic changes in the totalitarian period. That ends in 1990, when the post-industrial period begins. The final period 2005 documents the phase of attenuation of the effect of stress factors in the post-industrial period.

The newly formulated methodology indicates stress in the natural subsystem (ecological stress) and stress in the social subsystem (social stress). The total value is significant, but so are individual proportions at various time intervals. Stress present in the study areaindicates the action of stress factors located within the territory but also those outside of it. The negative action of stress factors does not respect administrative borders. In terms of terminology, the term stress relates to the internationally acknowledged methodical schema of the European Environmental Agency DPSIR ("Driving forces – Pressures – State – Impact – Response"), where it is an analogy to anthropogenic pressure in the landscape ("pressures").

Individual indicators represent the quality of a component aspect of the ecological and social subsystem. With regard to the fact that indicators do not have the same demonstrative capability, some are also distinguished by synergy effects, they have been allocated different weights. The selection of specific indicators and allocation of their weights was the task of an expert assessment commission made up of chosen foremost Czech and foreign specialists (from the Czech Republic, Germany, Poland and Slovakia). The actual process of calculating stress takes place in accordance with specialist methodologies based on points assessment. The numerical maximum range of the chosen indicator for the monitored territory are divided into quartiles. Numerical values are allocated as follows: in the low quartile ($Q_1 = 0$), below average ($Q_2 = 1$), above average ($Q_3 = 2$) and high ($Q_4 = 3$ points). They are multiplied by the relevant weights (1 or 2). Understandably, the ordinal level is important here, when assessing environmental stress variation range for individual indicators with a higher ordinal level increases and can also have a varying points scale. Analogically, with determination of individual intervals for specific quartiles the same methodology can be used for any other territory. Correlation analysis confirmed the significant autonomy of individual indicators. Pearson's correlation index did not exceed 0.6.

When calculating ecological stress present in individual components of landscape we firstly notice the levels of degradation of the topography and soils (Figure 3). For the Czech-German borderland a distinct anthropogenic transformation of topography is typical (surface mining of brown coal and quarries for construction stone – trachyte and phonolite), consequences of which are not only functional damage to the ecological subsystem but also disruption of the overall visual quality of the territory. The presence of black and controlled dumping was assessed using the 0 - 3 scale. The potential of water and wind erosion of the soil was calculated using an equation formulated by W. H. Wischmeier and D. D. Smith (Wischmeier and Smith, 1978). The variable was applied due to its agroenvironmental influences and its strong development changes in totalitarian period in Czech Republic. Air quality was assessed based on emission concentrations of solid substances, SO_2 and

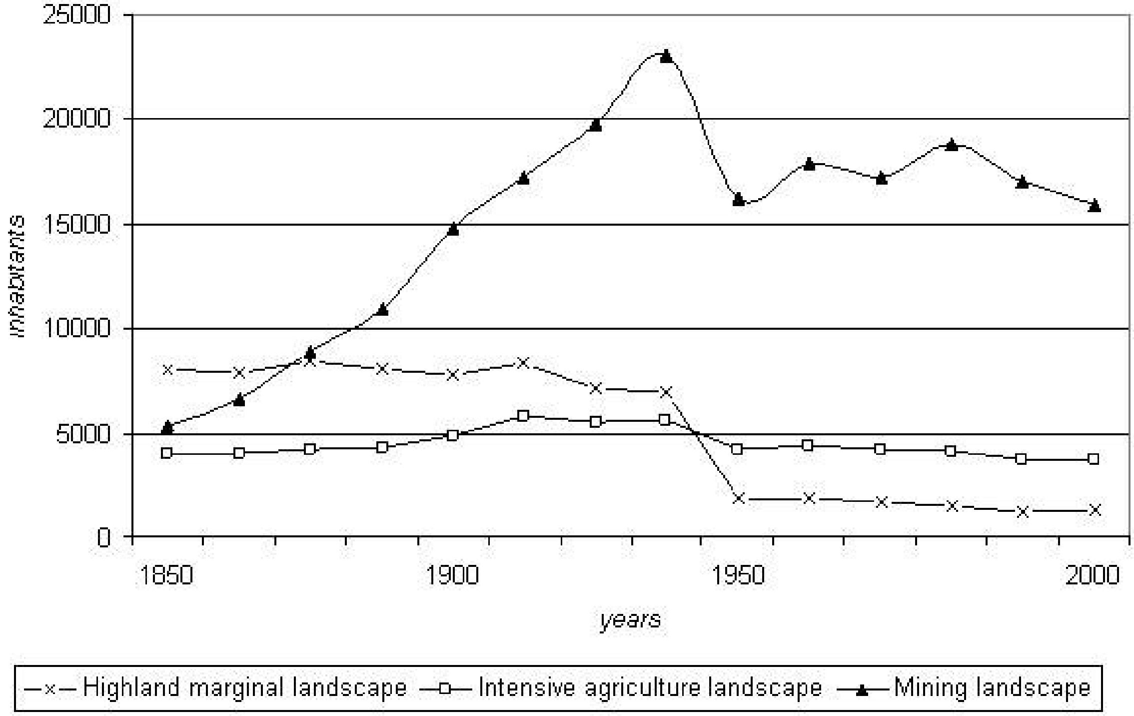

Figure 2. Number of inhabitants in study areas since 1850.

ECOLOGICAL STRESS

INDEX	GROUP	INDICATOR	SPECIFICATION	WEIGHT
A_1	Relief and soils degradation	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
A_4	Air pollution	Air pollution: SO2, NOx, air dust	mcg/m3	2
A_5		Local sources of air pollution	tons/km2	1
A_6		Noise and emission	intensity and frequency of traffic	2
A_7	Water quality	Surface water-course quality	quality factor	2
A_8	Biota	Forestal air pollution zones	prevailing category A, B, C, D, E, F	1
A_9		Ecological stability index	ratio of relatively stable and unstable land	1
A_{10}		Barriers	lenght of artificial-transportational ways km/km2	2

Figure 3. Ecological stress indicators.

NO_x and also by an indicator of air pollution from local sources (particularly from homes heated by solid energy sources). Surface water quality is shown by the indicator of water quality in water courses. Stress present in the landscape coverage reflects emission bands of forest species (proportion of forest species in a worsened health situation, according to defoliation of the crowns of individual trees in %) and an ecological stability index (proportion of relatively stable, natural ecosystems – forests, meadows and pastures, wetlands and water areas and unstable anthropogenic surfaces – built-up areas, fields, transport routes and other surfaces). With regard to fullness of information about stress in the ecological subsystem the calculation of the barrier effect and the presence of noise and smell cannot be left out. Fragmentation of a territory primarily by transport barriers was counted as density of transport routes (rail and road sections), and individual sections were also linked to transport intensity (number of vehicles or trains

SOCIAL STRESS

INDEX	GROUP	INDICATOR	SPECIFICATION	WEIGHT
B_1	Population change	Natality	average 5 years	1
B_2		Natural increase	average 5 years	1
B_3		Index of vitality	preproductive / postproductive	2
B_4	Family relation	Divorce rate	average 5 years	1
B_5		Incomplete families	in total	2
B_6	Economic relation	Index of education	university / elementary	2
B_7		Unemployment	average 5 years	2
B_8	Spatial movement - lability	Natives	in %	2
B_9		Migrational balance	average 5 years	2
B_{10}		Migrational change	average 5 years	1

Figure 4. Social stress indicators.

that travel along them in 24 h).Social stress assesses the social aspects that we think of as being negative. The set of assessment indicators therefore reflects the basic characteristics of the population in terms of social stress (Figure 4). Population movement is assessed using three indicators: vital index (proportion of pre-productive and post-productive residents), level of natality and natural population increase. With regard to the fact that the assessment process was related to the lowest ordinal administrative level of parishes, the two lastly named indicators have to be worked with five-year averages so that we eliminate random characteristics. The disturbance of family ties defines the ratio of incomplete to complete families and we determine the divorce rate as the number of divorces per 1,000 citizens in the given five-year period. We monitor the economic aspects of the population via the unemployment rate. An important indicator is education structure, monitored via the education index, calculated as the proportion of citizens with university and basic education. A significant group is represented by indicators with the help of which we observe the spatial movement of citizens. They implicitly demonstrate the relationship of citizens with the territory where they live. One of the indicators is the proportion of inhabitants born at the location where they live, another is the net migration indicating how attractive or unattractive the territory is. The third indicator is migration turnover demonstrating an unstable or “firm, fixed” relationship with the place where they live. Both of the last two indicators are monitored in a five-year range due to possible random events.

RESULTS

In the second half of the 20th century there were very distinct changes in land use categories. Despite the relative geographical proximity of study territories, the observed land use types demonstrate changes in development (Figure 6.). A fundamental tendency is the drop in arable land and the rise in so-called other spaces (particularly mining areas). The most dynamic drop in arable land was in the “highland marginal landscape” type (a drop to a quarter of the number it was in 1950) and the “valley basin” type (to 15% of what it was in 1950). Whilst for the valley basin type it was mainly for the benefit of other spaces (Figure 6, Table 1), for the “highland marginal landscape” type it was for the benefit of meadows (2x increase – Figure 5). There was also a slight drop in arable land in 1950 – 1990 for agricultural area (by 17%). At the same time there was an increase in the proportion of other spaces here (from 3.1 to 10.6). Whilst for “highland marginal landscape” type, which is densely forested, the proportion of forests between 1950 and 1990 kept increasing (from 27.7 to 34.6%), for other lightly forested types the proportion of forests stagnated.

Transformations of landscape functions of study areas in last 100 years

Petrovicko – highland marginal landscape type, where the structure and function of the landscape was totally transformed. The deserted territory was left to the natural process of succession. A “new wilderness” is being formed.

Třebenicko – intensive agriculture type, where still halfway through the 20th century a gently granular mosaic of agricultural landscape predominated, little fields separated by access routes bordered by woods, however subsequently by 2000 it was replaced by a coarsely granular agricultural landscape, with deserted, overgrown plantations in the background. Stable agricultural use was distinctly transformed into a micro-structure landscape.

Bílinsko – mining landscape type, where after 1930 a series of medium-sized and small settlements (even with 2,000 residents) had to give way to the large surface quarry of M. Gorkij in 1975. The overpowering process of urbanisation, industrialisation and development of the mining industry meant a transition from an agricultural landscape to a primarily mono-functional mining landscape (Figure 5).

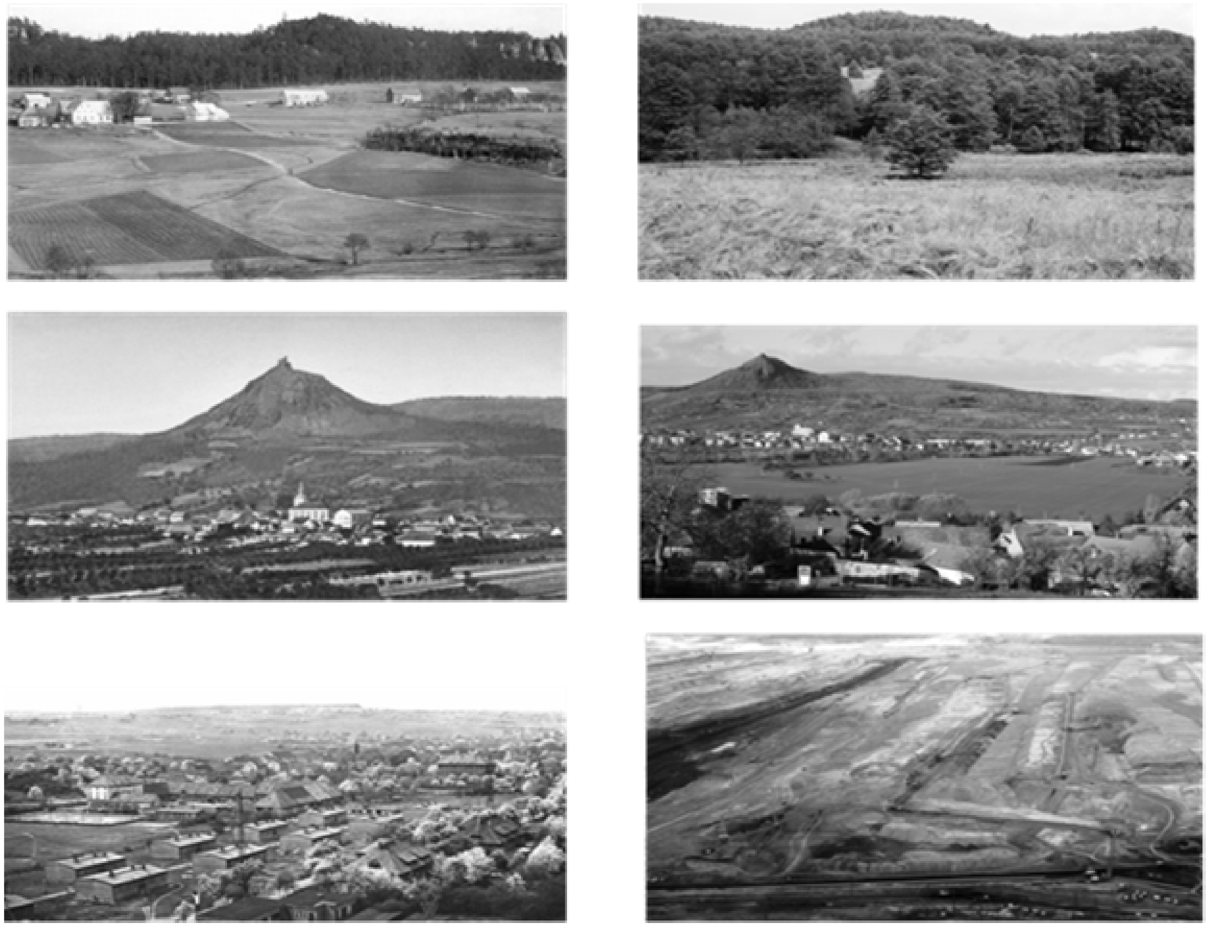

Figure 5. Transformations of landscape functions of study areas in last 100 years.

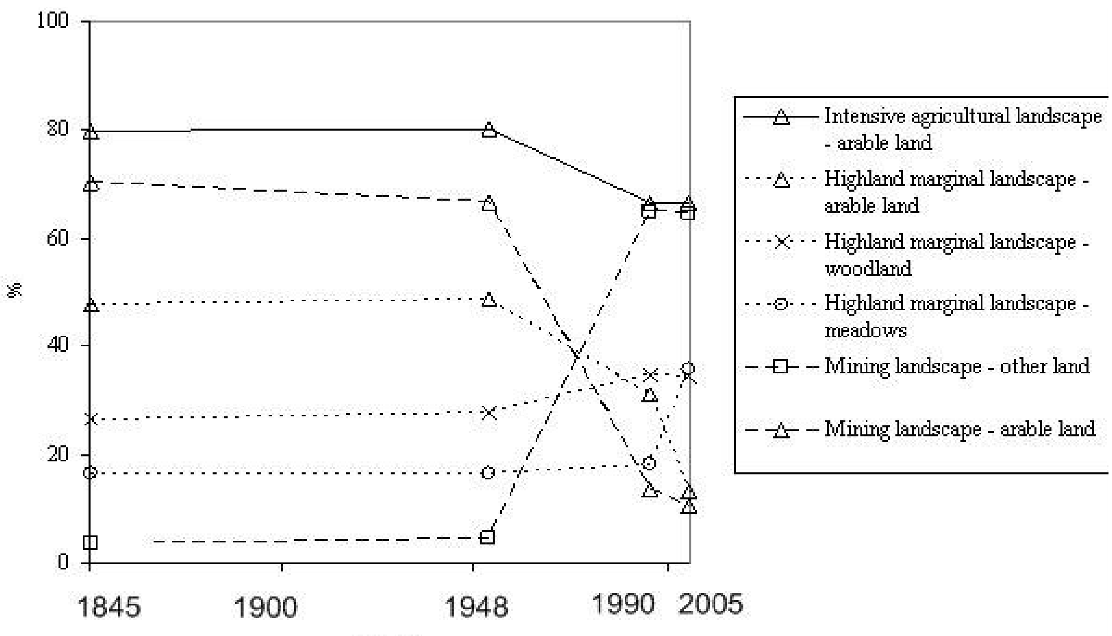

Figure 6. Land use changes in the study areas, selected land use cathegories with most dynamic changes (%).

Table 1. Changes of major land use cathegories in 1950, 1990, and 2000.

Type of landscape	Years	Forrest	Meadows	Arable land	Other land
Highland marginal landscape	1950	27,7	16,5	48,7	3,9
	1990	34,6	18,1	31,2	9,2
	2000	34,6	35,8	13,4	9,1
Mining landscape	1950	11,3	4,7	66,5	4,7
	1990	9,7	1,2	13,6	64,9
	2000	10,6	3,9	10,5	64,5
Intensive agriculture landscape	1950	5,4	3,2	80	3,1
	1990	5,8	0,9	66,6	10,6
	2000	5,8	0,9	66,6	10,9

Table 2. Fundamental characteristics of landscape types and level of their environmental stress.

	Mining landscape	Mountain periphery	Intensive agriculture
Geographical location	Regionally exposed	Semi- periphery	periphery
Location (in meters above sea leavel)	Pan (195-215)	Mountainous(450-750)	Lowland (170-260)
Intensity of EcoS	High	low	mean
Intensity of SocS	High	mean	low
Intensity of EnviS	EcosS>SocS	EcosS<SocS	EcosS=SocS

The development of ecological stress is confirmed by dynamic changes in the action of the most distinctive stress factors, which are electricity firms producing multiplicative stress effects in landscape components (Figure 7). A distinct increase in ecological stress up to 1990 is connected both with atmospheric pollution, as well as with the connected degradation of forest species, a growing level of anthropogenic transformation of the soil and a decreasing quality of surface watercourses. Conversely, a distinctly more dynamic drop in ecological stress after 1990 in all study territories is prevented by the stressing effect of growing intensity of transport, the resultant increase in noise and emissions from transport, increasing barriers, the persisting level of anthropogenic transformation of the topography and soil degradation and also the not improving health situation of forest species. The amplitude of changes of ecological stress reaches the highest values halfway through the 20th century at Třebenicko (350%), Petrovicko (almost 300%) and at Bílinsko (more than 200%). Among the three monitored territories, Bílinsko stands out by distinctly more intensively disturbed ecological subsystem. For all monitored indicators of ecological stress it attains the highest values.

The totalitarian period (the German occupation and communism, from 1950 to 1990) meant a disruption for the Czech-German borderland in its development and a disturbance of the continuity that had existed until then, which is also displayed in the dynamic growth in ecological and social stress. This disruption is, besides the distinct increase in the action of anthropogenic stress factors, linked with strong migration movements of the inhabitants, the displacement of Germans and the "new" settlement of the border area. The emigration of the German residents and the influx of new settlers from interior results in both quantitative changes (e.g. insufficient compensation for the emigrating residents, which is displayed between 1930 and 1950 by a population deficit of approx. 72% for Petrovicko, 30% for Bílinsko and 25% for Třebenicko), as well as qualitative changes (e.g. nationality, age, economic changes). The new population is distinguished by certain negative consequences: higher ethnic heterogeneity, unfavourable education structure and distinct social pathology (increase in criminality, drug addiction, divorce rates). On one hand, large settlement centres are growing and on the other hand there is a "demolition" of the structures of smaller settlements. As a consequence of not being settled after the war, two thirds of settlements in Petrovicko have disappeared and as a result of the development of quarry mining of brown coal only the sole town of Bílina remains in Bílinsko instead of the previous eight settlements. The new immigrants lose historic links to the territory and a togetherness with the landscape. In 1990 the proportion of natives in Petrovicko still was a mere 25% and with regard to migration strongly unstable trends predominate (high migration turnover). In the totalitarian period there was a constantly high negative net migration, as a result of the young generation leaving to go to towns and cities. A consequence of this is also a drop in the vitality index. The disturbance of family ties was emphasized and the proportion of incomplete families grew.

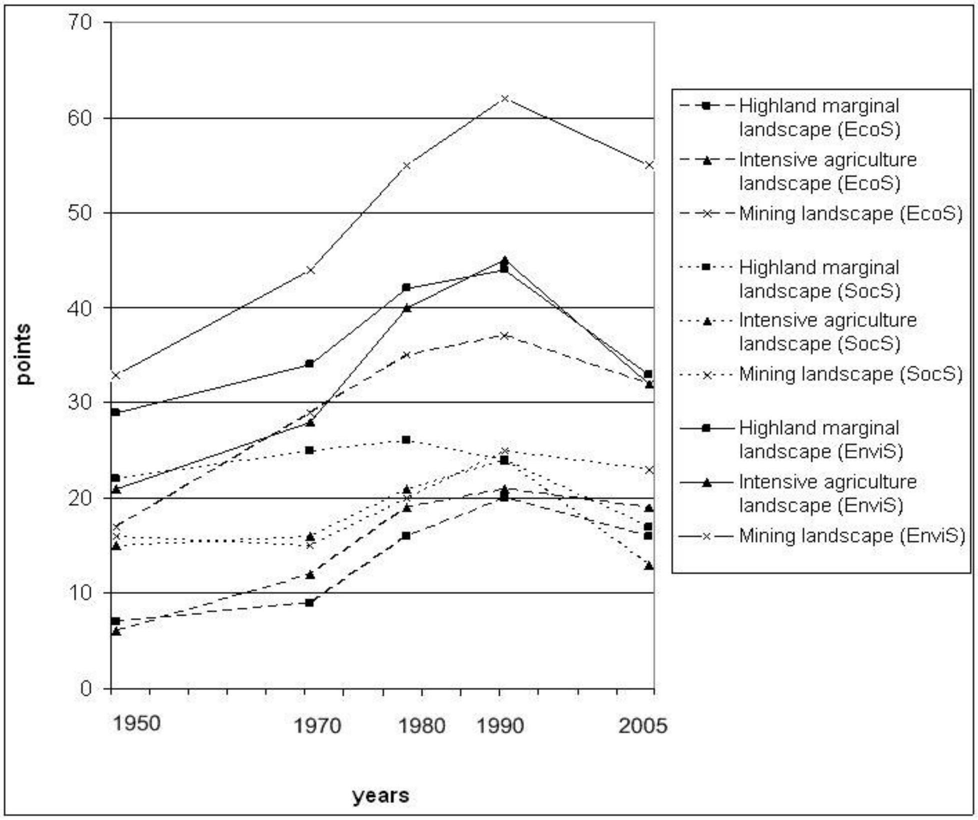

Figure 7. Changes of ecological stress (EcoS), social stress (SocS) and environmental stress (EnviS) in the study areas during 1950 - 2005 (observations per decades per land use changes in three landscape types).

Social stress records continuous accruals during the whole totalitarian period, when at its end they reached maximum values (accelerated particularly in the 1980s). The post-industrial period has a dynamic drop and a return to the level at the beginning of the totalitarian period (Figure 7). During its development we observe a selection in the development of individual study territories. This is given by different geographical location, population, social and physical geographical factors. The node point in the social stress level trend is 1990, when the observed areas reached almost identical values (around 25 points). The "paths" to achieving it were considerably different. Social stress in Třebenicko and Bílinsko after stagnation in the first half of the totalitarian period dynamically accelerated in its second part, particularly as a result of a drop in the vitality index, a reduction in natural accrual and particularly thanks to a loss in migration attractiveness. Conversely for Petrovicko social stress was very high already at the start of the observed period, after a significant increase in the 1st half of the totalitarian period (loss of migration attractiveness) there was stagnation. In the post-industrial period, social stress developed totally differently for the observed study territories. The most dynamic drop was seen by Třebenicko, which became attractive for migration again, the natural accrual increased, and the education structure surprisingly also distinctly improved. Petrovicko has similar characteristics and here there is also a dynamic increase in the proportion of natives and this strengthens the stability of the entire region. The situation in Bílinsko is different. There positive changes in indicators are advancing with a lot of difficulty. Compared to ecological stress, the amplitudes of changes are distinctly lower (maximum 150%). That indicates a larger dynamic in ecological stress in the second half of the 20th century.

DISCUSSIONS AND CONCLUSIONS

Based on fundamental development trends in combination with geographical location factors a very simplified typology can be carried out (Figure 6, Table 2).

1st type "mining landscape" – This is differentiated by a dynamic change to land use in the totalitarian period, linked with the elimination of settlements, concentration of residents into a core area and a totally dominating transformation of the basic functions of the landscape from agricultural gradually to industrial-agricultural and in the totalitarian period to urban and industrial-mining. Regionally exposed areas with a dominating mining and urban function of the landscape are distinguished by dynamic changes in land use (distinct decline in arable land for the benefit of mining space), an extremely high concentration of residents into large settlements and extensive interferences in the landscape. Negative anthropogenic impacts were displayed by an extreme growth in ecological stress (human effect on topography, pollution of the atmosphere and rivers in the totalitarian period), which significantly exceeds social stress. Overall environmental stress reaches its highest values among all types. Values of ecological stress distinctly exceed social stress. The 1st type is represented by a multi-centric core of the Krušné hory foothills pan area with dominating energy industry and mining functions.

The 2nd type, "highland marginal landscape", in the totalitarian period was distinguished by a strongly peripheral location. After the displacement of the German-speaking residents, a large part of it remained unsettled (drop in resident numbers of 72%). That was displayed negatively in the disturbance of settlement structure (elimination of two thirds of settlements) and a dynamic reduction in arable land as a result of a lack of labour. These trends also persist in the post-industrial period, when almost half of the area of arable land is replaced by meadows. The extensive agricultural function is gradually replaced in this final period by a recreational function. The relatively low level of ecological stress falls further in the post-industrial period, primarily as a result of a pervasive improvement in air quality. The level of social stress in the entire monitored period exceeds the level of ecological stress. An increase in the attractiveness of this type has a decisive effect on the drop in the post-industrial period. Migration turnover falls and the number of residents increases as a result of permanent immigration. The 2nd type represents the plateau of Krušné hory, a marginal territory mostly deserted and after the displacement of the German national residents it was not resettled with weakened historical ties of the residents to the landscape.

The 3rd type, "intensive agriculture", represents a stable type, with a stable settlement structure and relatively low reductions in the number of residents after the 2nd World War. It is characterised by only a slight drop in arable land in the totalitarian period. The agricultural function remains preserved throughout the monitored period, even though in the post-industrial phase other functions are also enforced, particularly recreational ones. Approximately the same, low values of both types of stress imply also a low value of environmental stress. The 3rd type is typical for intensively agriculturally utilised territories with quality soils suitable for plant production.

How will the Czech-German borderland develop and where will it be aimed? There are of course several versions of possible changes. The present distribution of three types of landscapes in the Czech-German borderland will evidently become even more homogenised (Figure 8). Future changes in land use will lead to a reduction in differentiation within the observed landscape types. For the valley landscape type in approximately ten years there will be a reduction in the proportion of other (mining) spaces in connection with landscape re-cultivation for the benefit of forest spaces, meadows and arable land. An increase in the proportion of water spaces is also expected as a result of hydrological re-cultivation (firing up of residual pits after surface mining of brown coal). The representation of land use categories will in this way distinctly even out. For the highland marginal landscape type, a fading trend of arable lad to meadows and pasture can be expected. This will finish off the transition from the intensive type of agricultural (plant) production in less favourable areas to an extensive method of rearing sheep and cattle. The representation of land use types in intensively agricultural landscape will change only slightly. This is attested by current efforts and projects aimed at strengthening ecological hydrological functions of agricultural landscape (installation of windbreaks, bio-corridors, live fences along the borders of plots of land and along water courses) and the already stabilised transition of formerly dispossessed agricultural land into private hands.

Prognoses indicate that for ecological stress in the following years a slight decrease can be expected in the beginning, followed rather by stagnation or possibly a slight increase. In connection with the following expected increase in the production of electricity or opening of new production blocks in subsequent years, possible larger changes in the concentrations of sulphur dioxide or nitrogen dioxide may also occur. The constantly growing intensity of transport will certainly contribute to their increase. The variability of emission concentrations of solid polluting substances in the air, especially in rural areas and in the winter months, also depends on the level of actual utilisation of energy efficient/environmentally friendly fuels in households. The most significant influences on other components of the landscape include the effect of the acidity of rainfall on the chemical attributes of the soil. As a result of acid rain, the pH value of soils fell by an average of approximately 0.5 in the monitored territories in 1971-1981. No improvement can be predicted in the trend for indicators of anthropogenic transformation of soils and topography. It is expected that the health situation of forest species will stagnate and in connection with global climate change secondarily planted spruce plantations at lower locations will suffer more significant damage. The intensity of negative action of linear stress factors maintains an increasing trend. Since the 1980s there has been at least a doubling and in some places an even higher increase in the total weight of vehicles on roads. A clearly negative consequence of this increase is on the larger fragmentation of the landscape by roads with more intensive transport. Noise and emissions from transport will increase.

Correlation analysis showed mutual cohesion of some indicators (e.g. natives or migration balance). It also re-

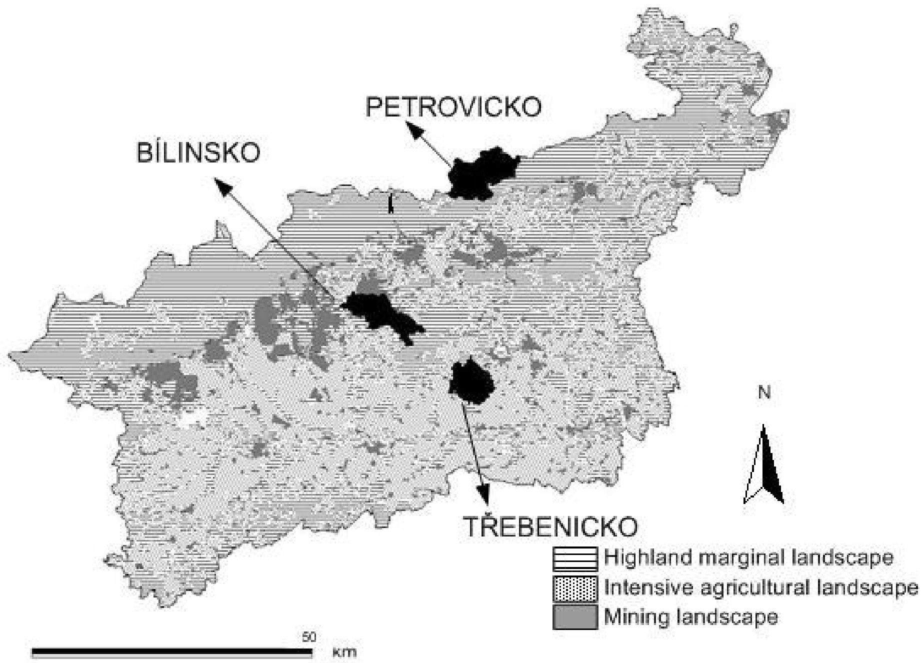

Figure 8. Similar three landscape types in 2005 (highland marginal landscape, intensive agriculture landscape, and mining landscape) within the Czech-German borderland.

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 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.

The future development of the social subsystem will be affected by external factors (particularly by the European population development) and internal factors (geographical location, attributes of the natural subsystem, local economic standard etc.). In comparison with the prognosis of ecological stress development the forecasts here are less clear. The population trend will observe Western European trends. This means that the low birth rate will continue to stagnate and the natural accrual will be minimal. A much larger share of the population will enter the higher age groups, which will result in a significant decrease in the vitality index. Evidently the divorce rate and proportion of incomplete families will also slightly increase. As a result of educa-tional reforms, the education and qualification structure of the population in the Czech Republic will improve. For the series of spatial movement (instability) indicators there will be an increase in the number of natives, and attrac-tive areas will constantly show a net migration. These facts can be well observed after the Czech Republic joined the EU. We forecast that overall in the Czech-German borderland there will be a deepening in the differentiation of individual locations in terms of the presence of social stress. Suburbanisation and re-urbanisation tendencies will be applied, disguising immanent differences between the urban and rural landscape.

The urgency of research into the presence of ecological stress in connection with social stress and in connection with changes to land use is confirmed by numerous studies, which demonstrate that in areas with a higher prevalence of stress in the ecological subsystem the intensity of selected medical difficulties is also higher (e.g. a higher percentage of children born with lower weight at birth and a higher percentage of children born prematurely, a lower level of overall and specific immunities and more frequent illness, more frequent occurrence of illnesses of the upper and lower air passages, higher occurrence of allergic illnesses, lower vitality and quality of sperm, higher overall, cardiovascular and tumour mortality, higher infant and newborn mortality, approximately 3 to 4 years lower average life expectancy than the Czech Republic average, longer sick leave, higher divorce rate, higher suicide rate etc.).

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