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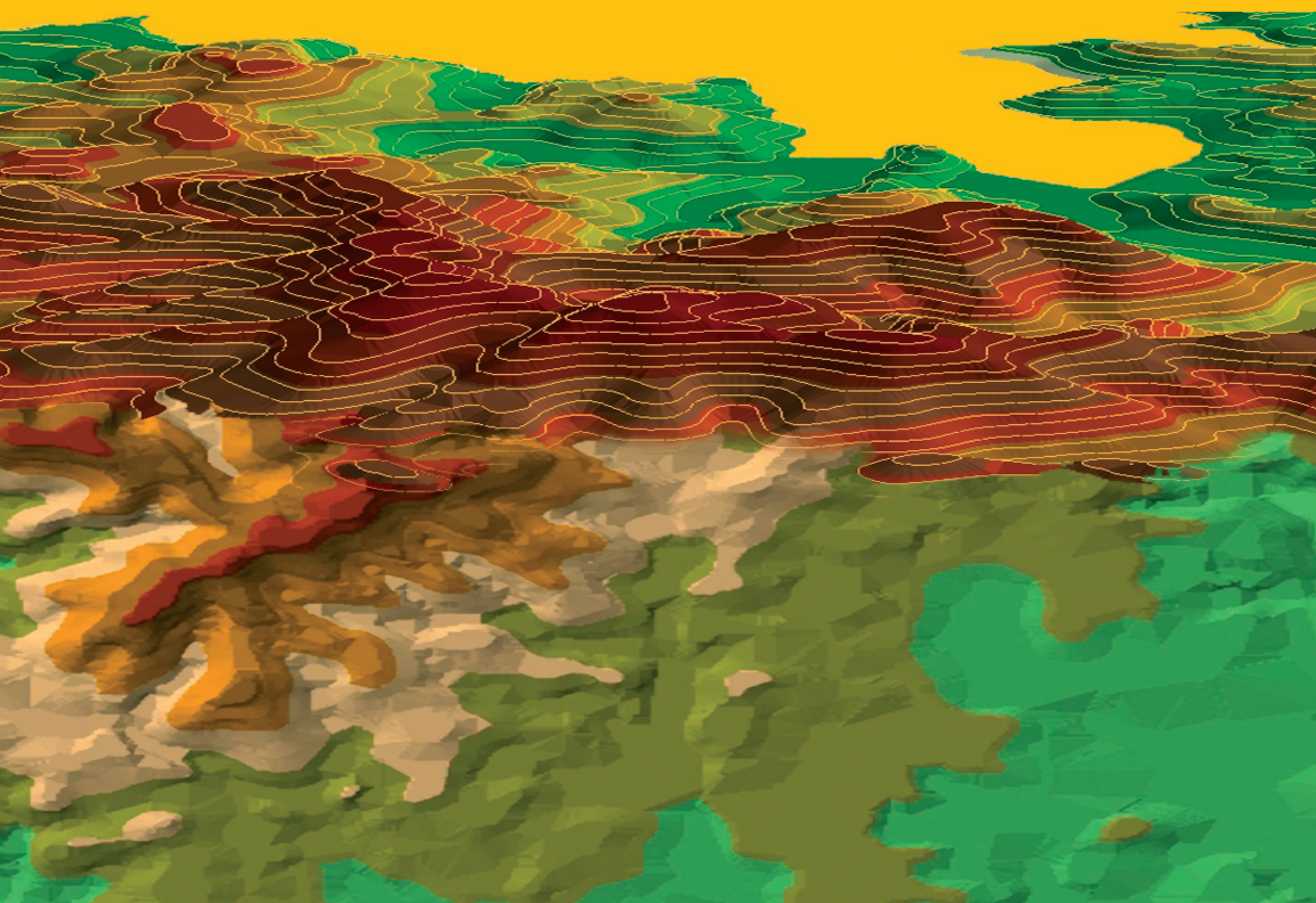

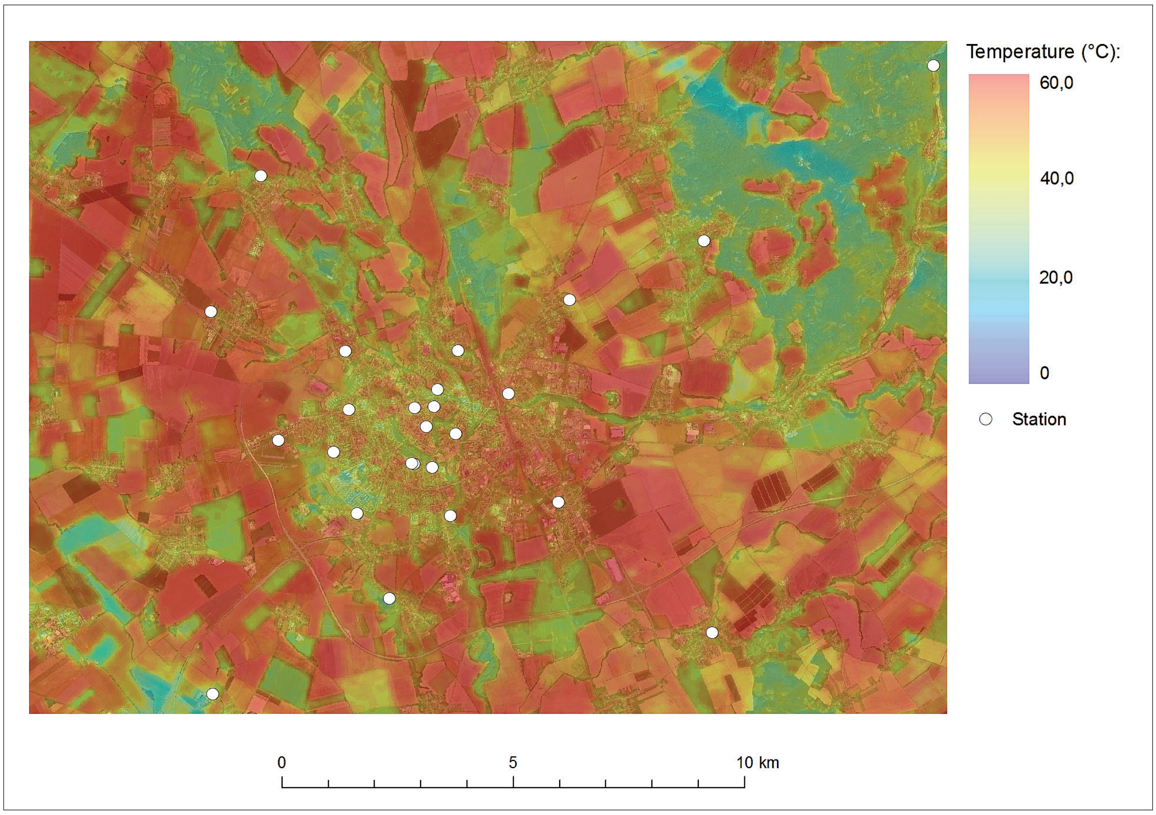

Fig. 7: Surface temperature field in Olomouc and its surroundings on 27th Sept. 2009 (source LANDSAT TM)

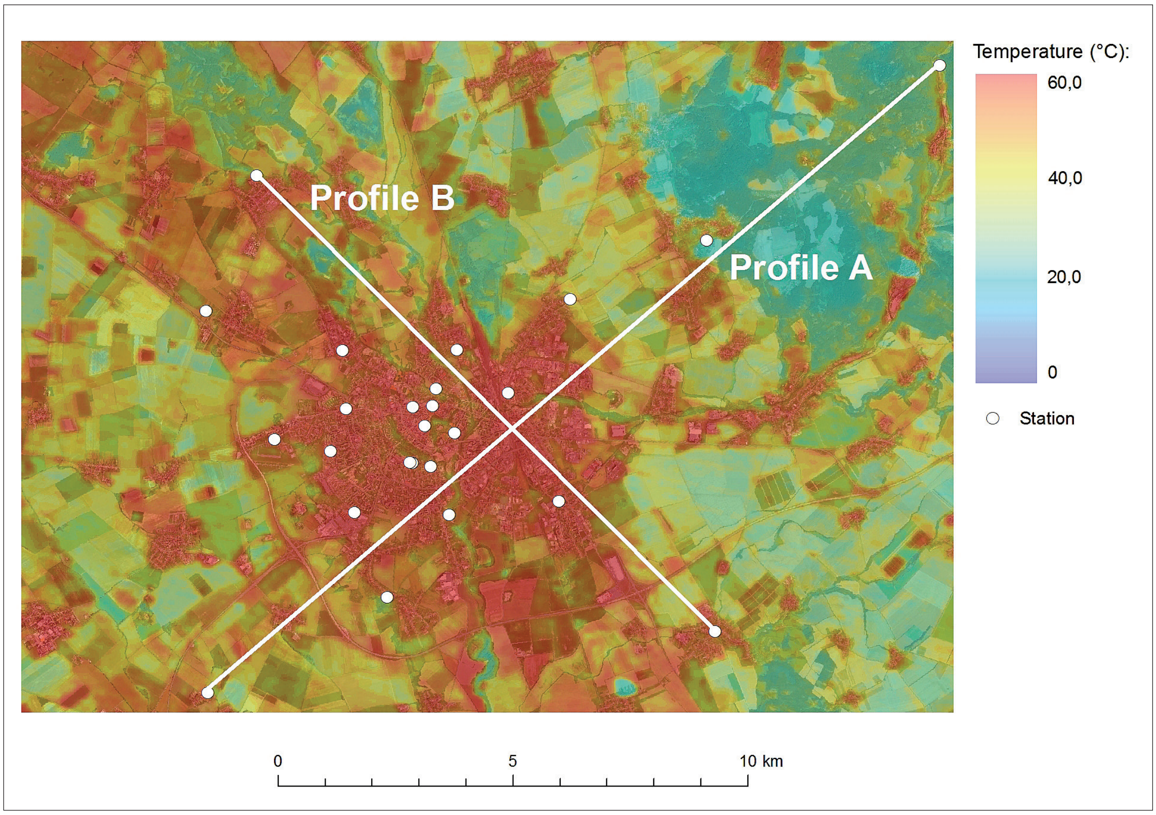

Fig. 8: Surface temperature field in Olomouc and its surroundings on 12th July 2010 and the line of surface temperature profiles a) BYST-DDHL, b) HORK-VTYN (source LANDSAT TM)

Illustration related to the paper by J. Geletič and M. Vysoudil

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MGR, Institute of Geonics ASCR, v. v. i.
Department of Environmental Geography
Drobného 28, 602 00 Brno, Czech Republic
(fax) +420 545 422 710
(e-mail) mgr@geonika.cz
(home page) http://www.geonika.cz

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Articles:

ANALYSIS OF SURFACE TEMPERATURES IN URBAN AND SUBURBAN LANDSCAPES FROM SATELLITE THERMAL IMAGES: A CASE STUDY OF OLOMOUC AND ITS ENVIRONS, CZECH REPUBLIC

Jan GELETIČ, Miroslav VYSOUDIL

Abstract

The spatial variability of surface temperatures in the urban and suburban landscapes of Olomouc is analyzed in this paper, based on the evaluation of thermal satellite images from LANDSAT-5 (TM sensor) and TERRA (ASTER sensor). The temperatures of active surfaces were determined by the use of appropriate algorithms. Maps of surface temperatures are presented. The non-homogeneity of the active surface and thus also the relative difficulty of analysis of surface temperatures is documented by the land cover map. The surface field temperature was compared with the values of the air temperature recorded at the weather stations. The analysis showed that the description of spatial differences in surface temperatures of a city and its surroundings, based on an evaluation of the thermal imagery, was inconclusive. The differences reflect the seasons, but above all the nature of the land cover in the suburban landscape. These findings will be used in a study of the temperature regime of Olomouc and its environs.

Shrnutí

Analýza povrchové teploty v městské a příměstské krajině na základě analýzy satelitních termálních snímků, Olomouc a okolí (Česká republika)

Příspěvek se zabývá prostorovou variabilitou povrchové teploty v městské a příměstské krajině Olomouce na základě vyhodnocení řady termálních satelitních snímků LANDSAT-5 (senzor TM) a TERRA (senzor ASTER). Povrchová teplota byla stanovena použitím algoritmů vhodných pro uvedené senzory. Jsou prezentovány mapy povrchových teplot v městské a příměstské krajině v různých částech roku. Nehomogenitu aktivního povrchu a tím i poměrnou obtížnost analýzy povrchových teplot dokladuje mapa pokrytí země. Pole povrchové teploty bylo porovnáno s hodnotami teploty vzduchu zjištěnými na meteorologických stanicích Metropolitní staniční sítě Olomouc. Analýza ukázala, že popis prostorových rozdílů povrchové teploty středně velkého města a okolí z termálních satelitních snímků je nejednoznačný. Rozdíly odráží roční období, ale především charakter pokrytí země v příměstské krajině. Poznatky budou využity při studiu režimu teploty v městské a příměstské krajině Olomouce.

Key words: *satellite thermal image, land cover, active surface, land surface temperature, air temperature, urban and suburban landscape, MESSO (Metropolitan Station System Olomouc), Czech Republic*

1. Introduction

Differences between the climate of a city and the climate of its surroundings, i.e. between urban and suburban landscapes, can be studied in many ways. The most detailed approach can be considered to be a multilevel monitoring of the regime of selected meteorological elements. Air temperature plays an essential role among them. One of these levels, the highest one, is monitoring of the surface temperature survey of selected (most spread) active surface types obtained from satellite thermal images. The knowledge is important because the thermal regime of the ground layer of the atmosphere is among other things closely bound with the regime of surface temperature (Land Surface Temperatures, LST).

A major problem when dealing with focused research on this topic is the high degree of non-homogeneity of the active surface in the city and its surroundings, which results in a spatially highly variable and a complex array of surface temperature. This temperature is directly responsible for the temperature regime in the ground layer of the atmosphere. This implies that an as accurate as possible knowledge of the land cover of the studied area is needed. The solution is the use of the database CORINE Land Cover, or determination of the surface type based on its emissivity or calculation from visible parts of the spectrum.

To verify the representativeness of results from the analysis of thermal images, we used - with respect to the functionality of the Metropolitan Station System Olomouc (hereinafter MESSO) – air temperature values recorded at the time of satellite passage, i.e., at moments when the photographs were taken. Air temperature in 2009 and 2010 was measured at 1.5 m above the active surface. For the year 2010, air temperature records were available from a limited number of stations measured at a height of 0.5 m above the active surface. Time differences of meteorological data readings and satellite scenes recording were insignificant. Maximum differences were 5' (LANDSAT-5) and 8' (TERRA).

Thermal satellite images have been used for some time in studying landscape and its components, especially in the field of climatologic research, and are described by many authors such as Adams and Gillespie (2006).

Van (2007) used remote sensing images from the ETM + sensor to determine relations between the type of land use and the surface temperature in an example of Ho Chi Minh city and its surrounding areas. LANDSAT satellite images were also analyzed by Nichol (1998) as described by Mesev (1998), who detected heat islands of Singapore and the Nigerian city of Kano. Calculating the surface temperature, he took into account the impact of buildings (geometry, height, number), which contribute to the resulting temperature value in densely populated areas.

The city heat island was studied also by Ozawa et al. (2004), who focused on densely urbanized areas in Japan. Nichol (1998) described average temperatures of individual agglomerations based on the evaluation of satellite thermal images. Detection of heat islands using thermal images in Brno was recently studied in details by Jelínek (2008) and Dobrovolný (2011).

Work on thermal imaging and obtaining information on surface temperatures was published by Weng and Yang (2006). They evaluated the Earth's surface temperature from a LANDSAT-7 image for studying factors contributing to air pollution in southern China. In other works, Weng, Lu and Schubringem (2004) and Weng and Lu (2006) studied the temperature field in Indianapolis using images from the satellites LANDSAT-7 and Terra (ASTER). Algorithms for obtaining surface temperatures were the same; they worked with surface categories to determine the emissivity values. Ganase and Lagiose (2003) used the night thermal imagery from LANDSAT-7 to obtain the surface temperature of the volcano Nissyros. The main objective was to assess the suitability of the LANDSAT image as a tool for monitoring the temperature regime of a volcano, using simple means of image processing (ERDAS, PCI). Stueven (2004) used thermal images of the Kilauea volcano from the LANDSAT satellite to compare temperature conditions on the images at intervals of three months. By unsupervised classification, using the ISODATA method, he obtained temperature scales which served only to compare temperature changes within the time interval.

2. Data and methods

During the implementation of this project, three data categories were analyzed – satellite thermal data, CORINE Land Cover database and meteorological data.

Satellite data

The selection of applicable satellite thermal images for the chosen period 2009–2010 was limited. One of the limiting factors was the existence of meteorological data from the Metropolitan Station System Olomouc (MESSO). The data were available in the desired range only for the years 2009 and 2010. The intention was to compare air temperature values measured at the stations with surface temperature values established by using thermal images. The second factor was that meteorological conditions characterizing the prevailing radiation weather had to exist in the studied locality at the time of taking the scenes by the satellite. Thus, only four scenes were available for the years 2009 and 2010 of the accessible databases of satellite images, moreover from different sensors. The used images then varied also by the spatial resolution in the thermal part of the spectrum.

Scene from 28th Sept. 2009, (9:52 UTC, 10:52 CET) was taken by the satellite TERRA and ASTER sensor and for the calculation of surface temperature it offers 5 thermal spectral bands (Band 10 – 8.125 to 8.475 μm, Band 11 – 8.475 to 8.825 μm, Band 12 – 8.925 to 9.275 μm, Band 13 – 10.25 to 10.95 μm, Band 14 – 10.95 to 11.65 μm) with a spatial resolution of 90 m.

Scenes from the satellite LANDSAT-5, sensor TM from 27th Sept. 2009 (9:34:43 UTC, 10:34:43 CET), 12th July 2010 (9:35:19 UTC, 10:35:19 CET) and 22th August 2010 (9:29:20 UTC, 10:29:20 CET) were in one thermal range 10.4–12.5 μm with a spatial resolution of 120 m.

Land cover data

Data on the character of the active surface were obtained from the CORINE Land Cover database 2006. Because the analyzed thermal images originated from different years and seasons, the information on the type of active surfaces were only preliminary. Describing the temperature field it was necessary to take into account the vegetation character in relation to the vegetation phase. Regarding the chlorophyll content and vegetation density, the values of surface temperature fields vary considerably during the stage of germination, ripening or at harvest time. The same applies, for example, for deciduous or mixed forests.

Meteorological data

Values of air temperature on days of taking the satellite images were obtained from measurements recorded at stations in the Metropolitan Station System in Olomouc (MESSO). The data were used to characterize the daily temperature regime during days on which the satellite scenes were scanned. At the same time, accurate values of air temperature were available at selected stations recorded at a height of 1.5 m at the time when the scenes were taken. Thus, it was possible to compare the surface temperatures and the corresponding air temperatures.

The ASTER scene was taken on 28th Sept. 2009, when the weather in the Czech Republic was under the influence of Wa situation. The oldest LANDSAT scene originates from 27th Sept. 2009, when the weather in the Czech Republic was also under the influence of Wa situation. The second LANDSAT scene is from 12th July 2010, when the weather in the Czech Republic was under the influence of Sa situation. Radiation weather (SWa situation) characterized the day of 22th Aug. 2010, when the last analyzed LANDSAT scene was taken. The daily course of temperature in those days was documented by records from the MESSO LETO station (Olomouc airport). The station in the outskirts of the town represents a typical suburban landscape. Active surface in its vicinity is formed by a well-kept lawn. Also, the daily temperature variation curves (Fig. 2) indicate the radiation regime of the weather.

2.1 Determination of surface temperature

Algorithms for determining surface temperatures

A common way for detecting actual surface temperature from the DN pixel value is known courtesy of physical laws. In specific cases, however, the calculation of surface temperatures is far more complex. The reason may be

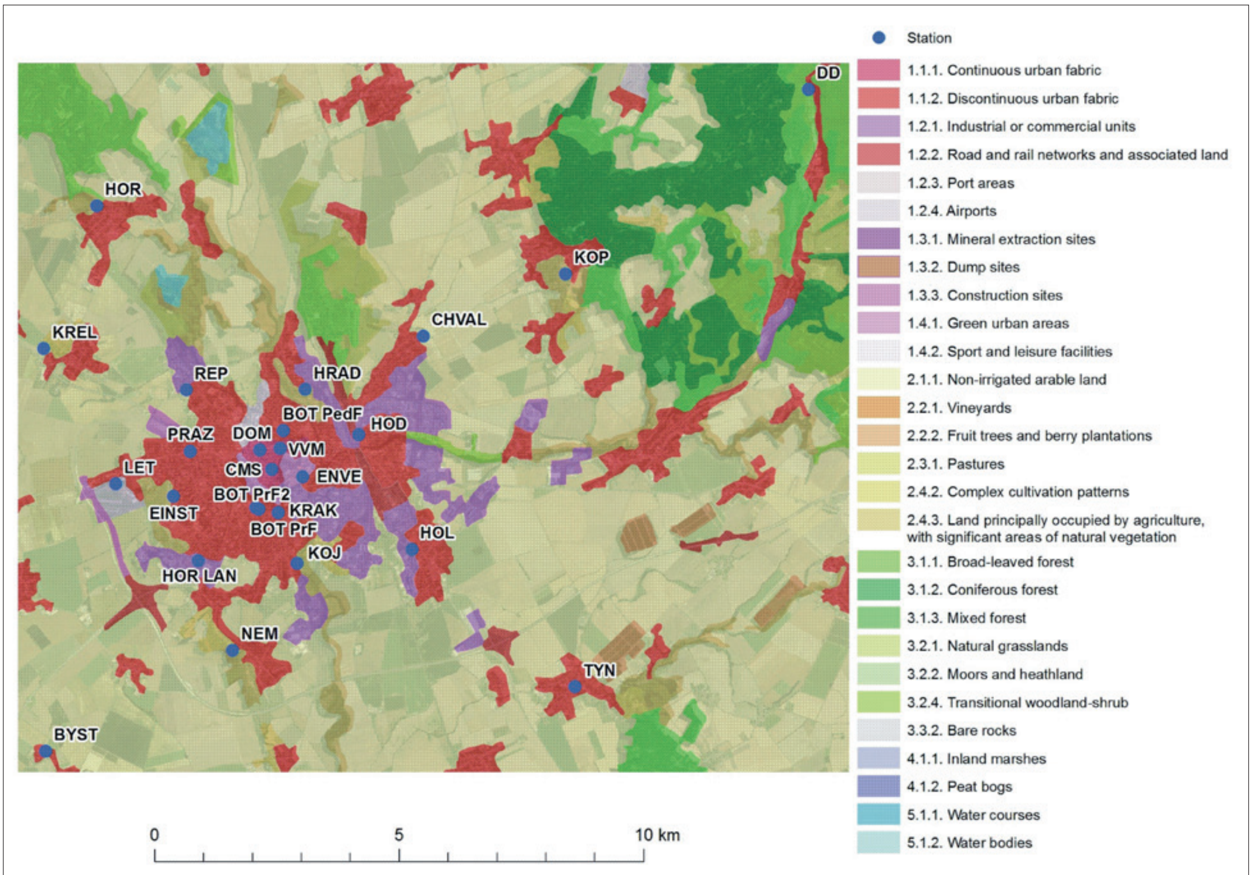

Fig. 1: Land Cover of Olomouc and surroundings with the MESSO network of stations (Source: CORINE Land Cover 2006, modified)

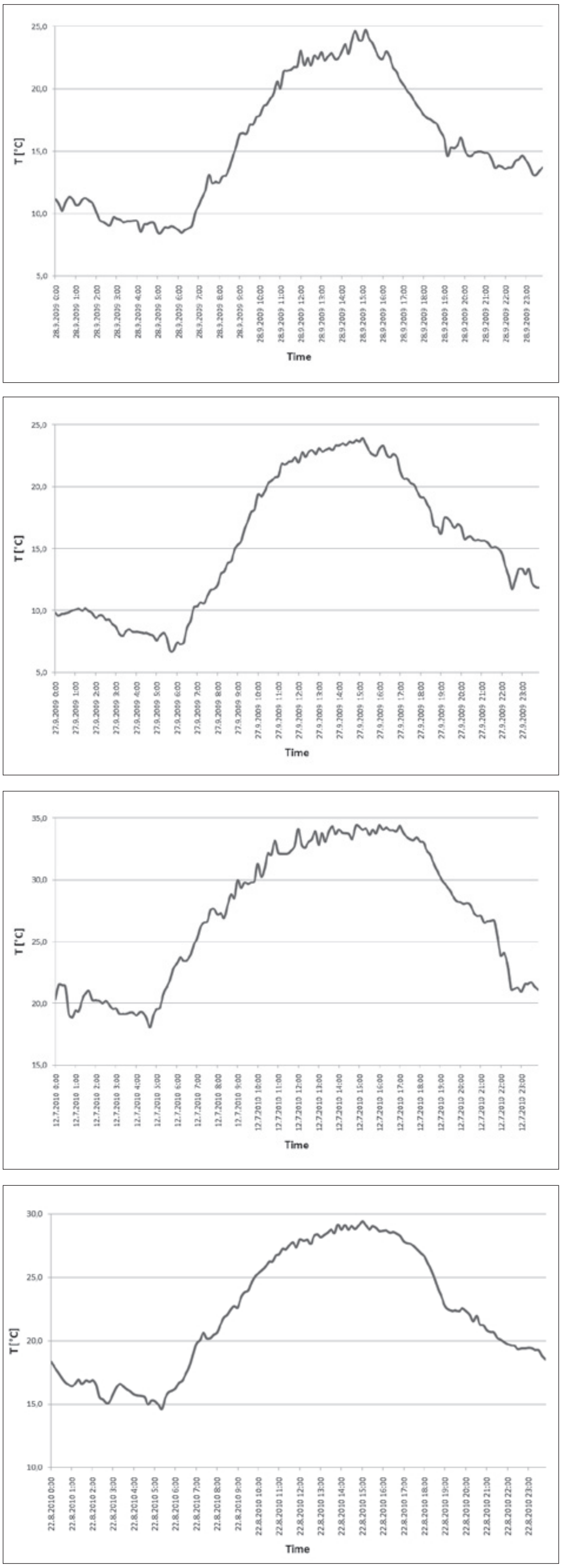

Fig. 2: The daily course of air temperature [°C] at the station MESSO LETO on days when thermal images were taken by the satellites ASTER a) 28th Sept. 2009 and LANDSAT b) 27th Sept. 2009 c) 12th July 2010, and d) 22th Aug. 2010

both specifics of the digital photographic record of the image (number of thermal zones) and, for example, also a need to eliminate the effects of the atmosphere. A number of algorithms have been published by now that have often been developed for the calculation of surface temperature (LST, Land Surface Temperature) from a specific sensor. With this in mind, the algorithms in the text for the calculation of surface temperature are described with emphasis on a concrete application data from the LANDSAT-5 and ASTER sensors.

Liang (2004) divided the most frequently used algorithms for calculating the surface temperature into so-called split-window algorithms and multispectral algorithms. As to the number of thermal zones used in the first mentioned case, the algorithms in question use two or more thermal zones. Data from LANDSAT-5 encompass only one thermal zone and this is why we used the so-called mono-window algorithms. For the purpose of our paper, we used the mono-window algorithms and the split-window algorithms.

Mono-window algorithm for LANDSAT 5

Application of this algorithm is typical for LANDSAT satellites with only one thermal zone (in the case of LANDSAT-5 TM6). This relatively simple algorithm for detecting temperature, introduced by NASA (Quinn and Karnieli, 2001), has been used in many works dealing with the mapping of urban heat islands.

However, the algorithm using only one thermal band has the disadvantage in that the detected temperatures are not free from the influence of the atmosphere. Therefore, Quinn and Karnieli (2001) developed and applied an algorithm for data from LANDSAT TM6 that models the state of the atmosphere by means of two basic meteorological indicators of the state of the atmosphere – transmittance and average atmospheric temperature.

The algorithm can be divided into three phases, which are sub-steps in calculating surface temperatures from the original DN value. Firstly, it is necessary to convert the DN value to spectral energy density of radiation having the wavelength L_{λ} (i.e. range of wavelengths in which the band picks up the interval 10.4 to 12.5 μm falling upon the sensor in units $m^{-2}\,sr^{-1}\,\mu m^{-1}$):

$$L_{(\lambda)} = \frac{L_{min(\lambda)} + \left(L_{max(\lambda)} - L_{min(\lambda)}\right)Q_{DN}}{Q_{max}},$$

where $Qmax$ is the maximum possible DN value ($Qmax$ = 255), Q_{DN} is DN pixel value, $L_{min(\lambda)}$ and $L_{max\,(\lambda)}$ are minimum and maximum detectable values of spectral density for $Q_{DN} = 0$ and $Q_{DN} = 255$.

According to NASA (2011), corresponding values for the LANDSAT-5 image are $L_{min(\lambda)} = 1.2378$ and $L_{max(\lambda)} = 15.303\ Wm^{-2} sr^{-1} \mu m^{-1}$, simplified as:

$$L_{(\lambda)} = 0.5515154\ Q_{DN} + 0.00485$$

Once the value of the spectral radiation is known, it is possible with the aid of the Planck function to calculate the radiation temperature T_{rad} [K] (brightness temperature), recorded by the sensor:

$$T_{rad} = \frac{K_2}{\ln\left(1 + \frac{K_1}{L_{(\lambda)}}\right)},$$

where K_1 and K_2 are calibration constants. Their values, according to NASA (2011) for LANDSAT-5 were determined as follows: $K_1 = 607.76\ Wm^{-2} sr^{-1} \mu m^{-1}$ and $K_2 = 1260.56$. If the emissivity of surfaces on the mapped area is known, a direct calculation of surface temperature is possible:

$$T_{KIN} = \frac{T_{RAD}}{1 + \left(\frac{\lambda T_{RAD}}{\alpha}\right) ln\varepsilon},$$

where λ is the wavelength of emitted radiation (in our case corresponding to the mean value of wavelength limits for LANDSAT thermal band) i.e.

$$\lambda = 11.45\ \mu\text{m},\ \alpha = hc / K = 1.4382 \times 10^{-2}\ \text{m}K$$

where K is the Stefan-Boltzmann constant, h is the Planck constant and c is the speed of light. The correction of temperatures to atmosphere is possible using the Karnieli and Quinn's formula (2001):

$$T_{KIN} = \frac{a(1 - C - D)(b(1 - C - D) + C + D)T_{RAD} - DT_A}{C},$$

where a, b are coefficients according to Quinn and Karnieli (2001) described in Tab. 1, T_A is average effective temperature of the atmosphere and for parameters C and D implies:

$$C = \varepsilon\tau, \qquad D = (1 - \tau)[1 + (1 - \varepsilon)\tau]$$

where ε is surface emissivity and τ is atmosphere transmittance.

It follows from the above that surface temperature corrected by atmospheric effect can be calculated from the radiation temperature. For this however, it is necessary to know the emissivity of surfaces and the average temperature and transmittance of the atmosphere. Surface emissivity can be calculated for example from NDVI index values (Liang, 2004), or the emissivity values can be established by using tables for the individual types of surfaces (Asmat, 2003).

According to Quinn and Karnieli (2001), the average temperature of the atmosphere can be derived – if more accurate data are not available - from air temperature at a height of 2 m by using the model of standard atmospheres. Transmittance can be calculated in a similar way from the values of water vapour content.

Multispectral algorithms

In the case of mono-window algorithm, the key knowledge for determining the surface temperature is that of emissivity, determined by some external means. This can be for example from vegetation indices, through the surface classification into several classes of known emissivity, or from other sources (e.g. CORINE Land Cover). By contrast, in the case of multispectral algorithms a very accurate way to determine emissivity is its detection directly from the thermal bands (Liang, 2004), i.e. by separating the information on surface temperature and emissivity directly from values recorded on the multispectral image. This is why the multispectral algorithms are referred to as "methods of temperature and emissivity separation – TES". The condition for the existence of multiple thermal zones and hence for the application of this method is met for instance by the sensors MODIS and ASTER.

For multispectral algorithms it is necessary to correct atmospheric effects before separating emissivity values and temperatures of a multiband thermal image. Then it is possible to determine both the surface temperature and the emissivity from the multi-spectral thermal image. However, effects of surface temperature and emissivity are so closely connected in thermal infrared radiation that their separation from thermal infrared radiation detected by the sensor is relatively difficult. This is because one multi-band thermal measurement of N zones represents N equations with N + 1 unknown factors (N emissivity values and surface temperatures).

Temperature range [°C]	Coefficients	
	a	b
0–30	– 60.3263	0.43436
10–40	– 63.1885	0.44411
20–50	– 67.9542	0.45987
30–60	– 71.9992	0.47271

Tab. 1: Coefficients of the calculation of atmospherically corrected surface temperatures according to Quinn and Karnieli (2001)

Without a priori information it is impossible to determine exactly either the surface temperature or emissivity. Most of these algorithms add to the system of equations one empirical equation in such a way that using the given N measurements (ranges) and this empirical equation is then possible to find out N + 1 unknown factors. Regarding the available data, key methods for this work are those dealing with data from the ASTER satellite (Gillespie et al., 1998; Gangopadhyay et al., 2005). The practical calculation of temperature is as follows. First, it is necessary to convert DN values into spectral density values for all thermal zones. According to NASA (2011 [online]), this is possible simply through multiplying the DN value by the value of the "band scale factor" coefficient (Tab. 2). The subsequent conversion of spectral density values to radiation temperature (T_{RAD}) was studied in detail by Alley and Jentoft-Nielsen (2001).

The influence of the atmosphere can be eliminated from thermal images by calculation, which uses only these thermal data (IEEE, 2004 [online]). The type of algorithms known under the name ISAC (In-Scene Atmospheric Compensation Algorithm) is often implemented in programmes designed for the processing of remote sensing images and is fully automated.

The algorithm assumes that atmosphere above the entire image is more or less homogeneous and that an object occurs on the scene whose radiation characteristics are very similar to radiation characteristics of a perfectly black body. However, it does not take into account the counter radiation of the atmosphere. First, the algorithm determines a wavelength, which most often radiates at a maximum radiation temperature. This wavelength is then considered as a reference. Only that part of the spectrum which has its radiation temperature on this wavelength is used to calculate atmospheric corrections. Dependences of absolute black body radiation and measured radiation values are then plotted for each wavelength in the correlation field. A regression line is fitted through this created field of points. Correction of this band is then applied as regression line slope and shift detected from the linear dependence of these data with the calculated absolute black body radiation at a corresponding wavelength.

Spectral band	Wavelength	Band scale factor
10	8.125–8.475	0.006882
11	8.475–8.825	0.00678
12	8.925–9.275	0.00659
13	10.25–10.95	0.005693
14	10.95–11.65	0.005225

Tab. 2: Parameter Band Scale Factor for the ASTER sensor

Upward radiation of the atmosphere and its transmittance can be expressed approximately as follows. First, surface temperature is determined for each pixel from the data and used to approximate radiation temperature using the Planck function and setting the emissivity value at a value of one. Then a regression line is fitted through the correlation field of the dependence of spectral density and radiation temperature. Upward radiation of the atmosphere and its transmittance are then obtained from the slope and the shift of the regression line.

Multispectral algorithms for ASTER

These algorithms known as TES were developed specifically for ASTER data. With their help, surface temperature and emissivity can be easily detected. They typically use a certain simplification for the reduction of unknowns (GILLESPIE et al., 1998). It should be noted that results of the practical application of these algorithms are often more focused on the use of emissivity rather than surface temperature, because exact emissivity is a very valuable source of information about the type of surface.

Normalized Emissivity Method (NEM)

This procedure calculates the surface temperature for each pixel and the range from data using a constant emissivity value. An often selected value for this constant is 0.95 or 0.96. The highest temperature is then regarded as temperature of the pixel. This high temperature serves also for the calculation of emissivity for the given pixel using the Planck function. These two methods were compared by Gangopadhyay et al. (2005) with data obtained from field measurements by using the precision radiation thermometer. A surface that was chosen for data validation was highly homogeneous water surface.

Calculation of surface temperatures

Of the two above-described methods, the mono-window algorithm for LANDSAT-5 is simpler. The procedure is relatively easy to implement in the GIS environment. The environment chosen for the work was that of ArcGIS 9.3. The biggest drawback of this algorithm is apparently the ignorance of emissivity of surfaces in the studied territory. Another disadvantage is a more difficult option of atmospheric corrections. Emissivity was calculated from the first three bands of the LANDSAT satellite by using the eCognition programme.

In the case of the algorithm for ASTER, it is not necessary to know the emissivity of surfaces. Even the atmospheric corrections are made by using the already pre-defined algorithms. Surface temperatures were calculated by using the ENVI 4.7 programme.

Surface temperature calculation for LANDSAT TM

Surface temperature was calculated by using the above-described mono-window algorithm applied in ArcGIS 9.3 (module ArcMap 9.3) using the extension of Spatial Analyst as a superstructure for working with raster data. Thus, surface temperatures are then corrected by the contribution of the atmosphere. The data flow is presented in a flowchart (Fig. 3).

The processing of the LANDSAT data consisted of two parts: map of radiation temperatures and map of surface emissivity. From these two parts, the surface temperature for each pixel can be calculated easily. Average effective atmosphere temperature can be detected by using the model of standard atmospheres. In this case, the following relation was chosen for the summer atmosphere of temperate latitudes (mid-latitude summer):

$$T_A = 16.0110 + 0.92621\ T_0$$

where T_0 is temperature at a height of two meters above the ground. At the time of the image taking the temperature was 20.36 °C. The value of transmittance was set at 0.8666750.

Surface temperature calculation for ASTER

Surface temperature was calculated by using the NEM algorithm because it is often applied in practice and is implemented in the software ENVI 4.7 used for the calculation. A characteristic difference of ASTER data processing is that the calculation of surface temperatures is entered by all five bands. First, it was first necessary to convert DN values to spectral density values and subsequently to correct them by the effect of the atmosphere. The actual surface temperature calculation by the NEM method requires entering the emissivity value on the input that will be used to calculate the temperature. The default value of 0.95 was chosen, which is -according to many available resources- the most frequently used value. The work procedure is shown in the diagram (Fig. 4).

2.2 Determination of the spatial differentiation of temperature field in urban and suburban landscape

In addition to the visual interpretation of the temperature field from the analyzed thermal images and land cover maps, the spatial differences on the selected pairs of images (ASTER 28th Sept. 2009 and LANDSAT TM 12th July 2010) were documented by parallel profiles of the surface temperature. Profile a) ran between the stations MESSO BYST-DDHL approximately in the SW-NE direction, profile b) between the stations HORK-VTYN in the NW-SE direction. The mentioned scenes showed the most significant surface temperature differences between the urban and the suburban landscape.

The values of surface temperature at the location of the selected stations were then compared with the values of the air temperature at a height of 1.5 m

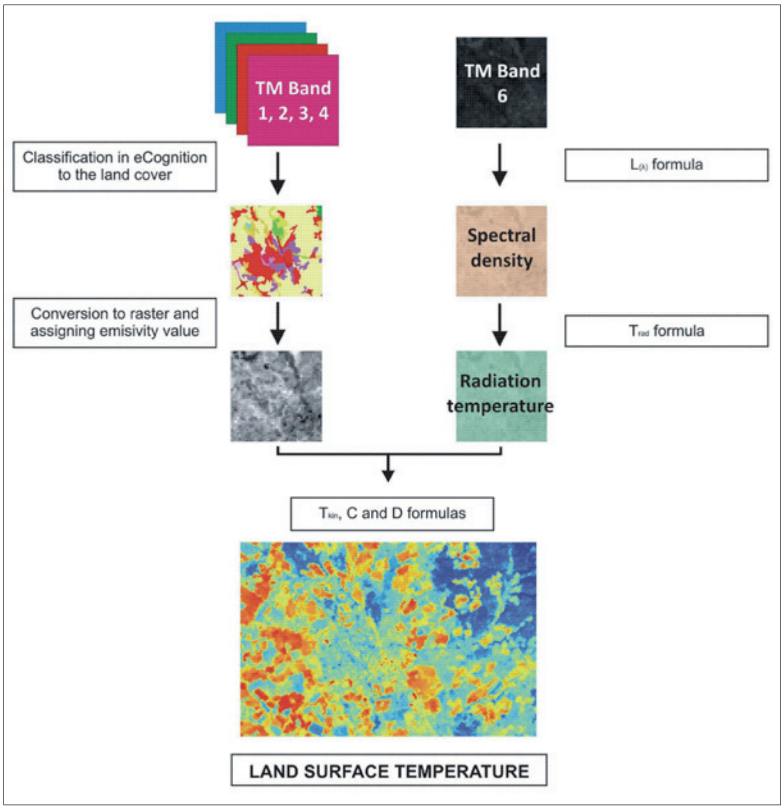

Fig. 3: Procedure of LANDSAT TM data interpretation

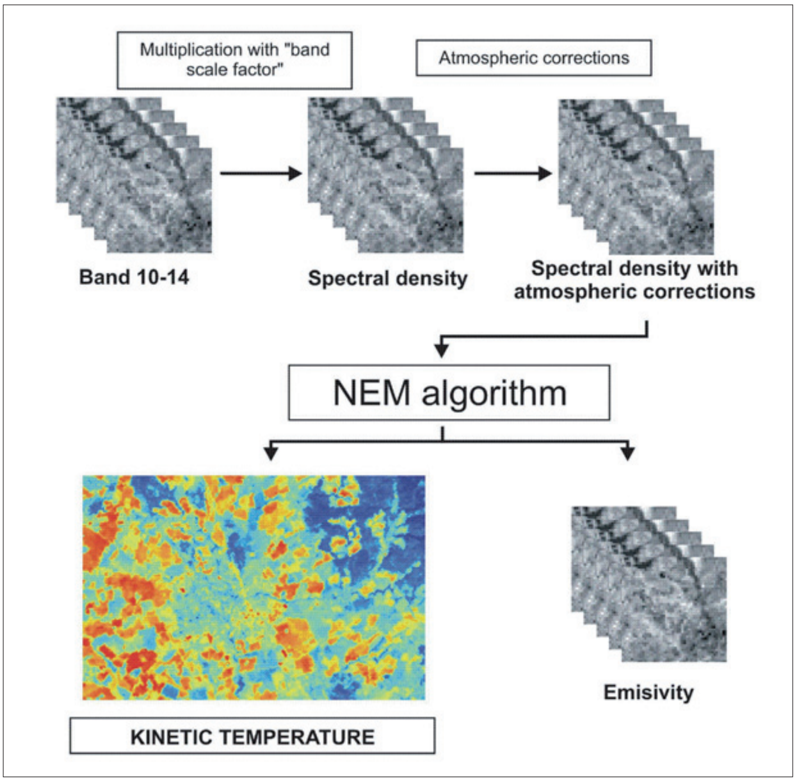

Fig. 4: Procedure of ASTER data interpretation

on these stations. Positive differences had been anticipated in favour of the surface temperatures. Empirical reasoning was sought for any negative differences based on the knowledge of the active surface character near the station. It was necessary to take into account the fact that the size of individual pixels was 90 × 90 m, resp. 120 × 120 m. On such an area, the active surface in the urban and suburban landscapes can be considerably inhomogeneous. As a result, there may be significant horizontal variations in the surface temperature (Figs. 6 and 9), which the thermal image cannot capture because of spatial resolution. However, if the station occurs within such a pixel and at the same time above the specific active surface, the temperature at this station may be affected exactly by its specific thermal properties. Then, its value may be lower than the corresponding calculated surface temperature of the given pixel.

3. Results

The presentation of results includes firstly the description of surface temperature field in Olomouc and its surroundings, as detected from the analysis of thermal LANDSAT and ASTER satellite images in four time periods in 2009 and 2010. All images were taken in the months of July, August and September, i.e. in the main growing season and at its end. It was especially this fact that affected the rate of temperature field differences between the urban and the suburban landscape. The second part of results is represented by air temperature values recorded on the MESSO meteorological stations at a height of 1.5 m above ground and their comparison with surface temperature values calculated for the station surroundings from the thermal images.

3.1 Surface temperature field

Generally it is assumed that the town's territory will show on thermal images with predominating artificial surfaces as significantly warmer. The results were not so conclusive, though, and the most likely reasons would be the time when the images were taken and the state of vegetation in the suburban landscape at that time.

The surface temperature field determined by analyzing the ASTER image from 28th Sept. 2009 (Fig. 5) is characterized by lower temperatures in the inner town. The warmest part of the town is represented by the SE part with a high concentration of artificial surfaces. Lower surface temperature values relate to most rural areas in the immediate surroundings of Olomouc. Significantly lower are the surface temperatures of forests and watercourses. Agricultural plots dominate in the suburban landscape as conspicuously warmer. The high temperature values of these plots reflect the thermal characteristics of bare cultivated farmland after harvest and agricultural work, i.e. in the absence of vegetation. The great horizontal variability of the temperature field in the autumn season is documented by temperature profiles between the stations BYST-DDHL and HORK-VTYN (Fig. 6).

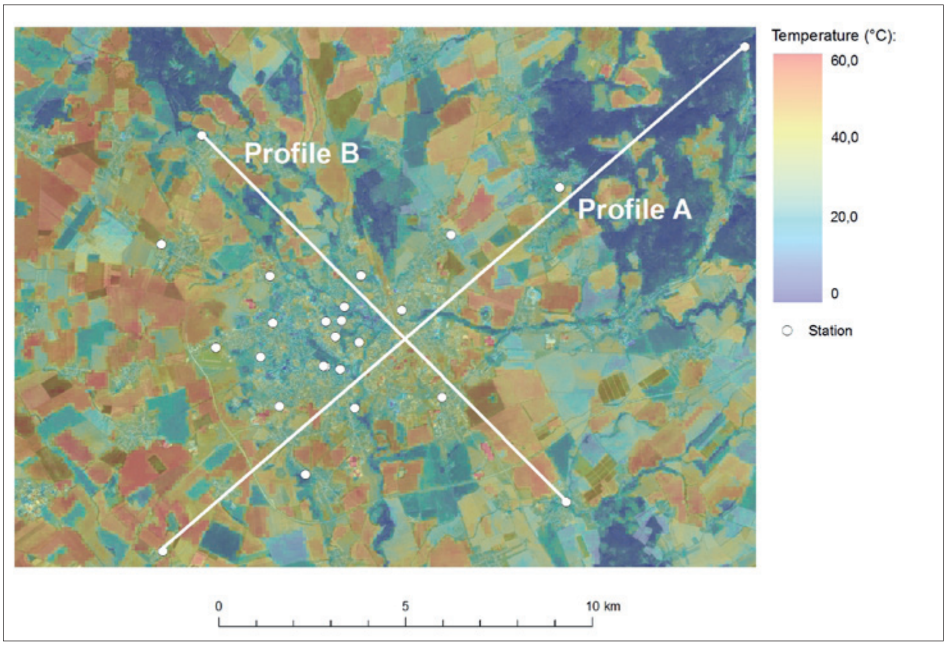

Fig. 5: Surface temperature field in Olomouc and surroundings on 28th Sept. 2009, 10:52 CET and the lines of surface temperature profiles a) BYST-DDHL, b) HORK-VTYN (source ASTER)

The LANDSAT image (27th Sept. 2009) was taken one day before the presented ASTER scene. The surface temperature field (Fig. 7 – see cover p. 2) is thus very similar to the analyzed ASTER scene. Neither the inner city nor the surrounding rural settlements show to be conspicuously warmer areas. They again represent agricultural areas with no vegetation in the suburban landscape. Forests in the NE part of the studied area are again clearly the coldest.

Very conclusive results about the function of urban areas as heat sources were harvested from analyzing the LANDSAT scene (12th July 2010). It was taken at a time when a greater part of agricultural areas surrounding Olomouc were covered by green vegetation whose thermal properties made it colder than the artificial surfaces of the city (Fig. 8 – see cover p. 2). As a heat island in the landscape, the town stands out quite clearly. This is also evident in the temperature profiles (Fig. 9) between stations a) BYST-DDHL and b) HORK-VTYN. Meteorological conditions undoubtedly played a role, since practically the entire second decade of July 2010 was characterized by tropical temperatures and the surface of the city was constantly overheated.

The surface temperature field in the urban and suburban landscapes of Olomouc obtained from the thermal image Landsat (22th Aug. 2010) shows insignificant spatial differences (Fig. 10). Artificial surfaces of the inner city and agricultural areas in the post-harvest season behaved almost identically. However, the warmer area in the city is once again represented by its SE and S parts. Extensive areas of "green" forest stands and larger water bodies are clearly the coldest.

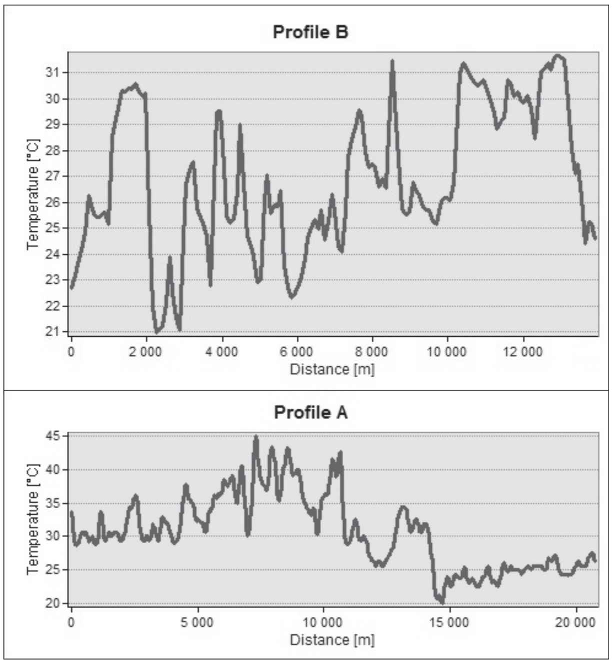

Fig. 6: Surface temperature profile between the stations a) BYST-DDHL, b) HORK-VTYN

3.2 Surface temperature and air temperature

The relevance of surface temperature values established by analyzing thermal satellite images was assessed by comparison with the air temperature values recorded by MESSO at a height of 1.5 m ((Tab. 3). Temperature records from the KOPE, DDHL, BOT_PeF, LETO, BYST and DOMI stations were available for all days, whereas from the stations ENVE, JUTA they were available only for 12th July 2010 and 22th Aug. 2010.

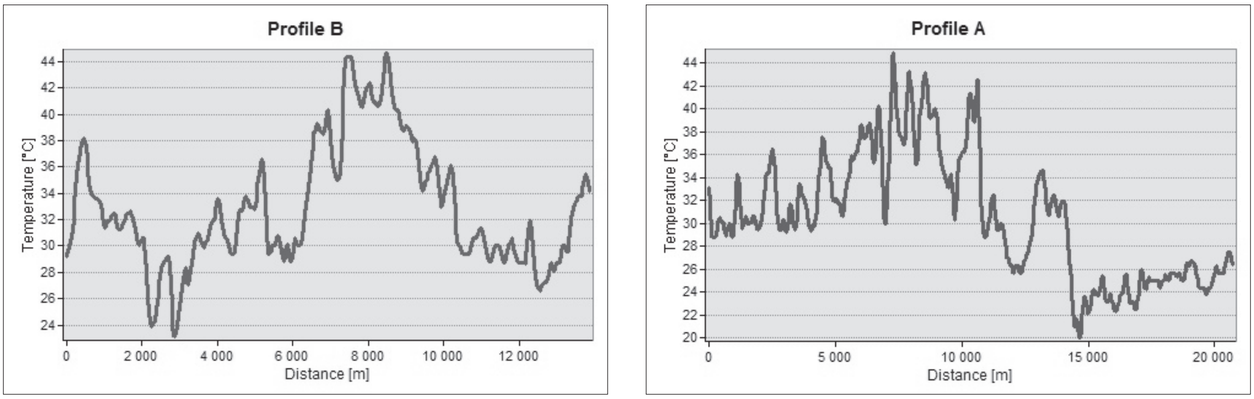

Fig. 9: Surface temperature profile between the stations a) BYST-DDHL, b) HORK-VTYN

Surface temperature (LST)

The level of surface temperature at selected stations in all time periods is evident from Fig. 11. It follows quite clearly from these data that the suroundings of the DOMI, JUTA and LETO stations are the warmest at all times. As the stations are of typically urban and suburban (LETO) character, it can be stated that the temperature is affected here mainly by the nature of the active surface.

On the other hand, always cooler were the DDHL, KOPE and BYST stations (except for the date 28th Sept. 2009). None one of these stations is typically urban. In these cases, we are probably dealing with a combination of the georelief form and active surface effects on the temperature regime.

A very similar character of the surface temperature field was observed on the ENVE and BOT_PeF stations. These represent the type of town stations with the ENVE station being located on the flat roof of a building and the BOT_PeF in the botanic garden. The types of the active surface are rather similar at these stations (gravel or land with sparse grass stand).

Regime atmosphere temperatures in the study area on 12th July 2010 document the air temperature values at 1.5 and 0.5 m above surface, where at most stations the values on the ground are significantly higher and reflect properties of the active surface in their vicinity (Tab. 4, Fig. 11).

The principle of warming the ground atmosphere on 22th Aug. 2010 from the active surface confirm the value at the stations MESSO at heights of 1.5 m above surface (Tab. 4).

Air temperature

The values of air temperature at 1.5 m above the ground for all days were available only for stations presented in Tab. 3.

From Tab. 3, it is obvious that air temperatures on the observed days and times characterized the temperature of individual stations generally in the same manner. While the DOMI and BOT_PeF stations were practically always the warmest, the DDHL, LETO and BYST stations ranked with the coldest ones.

Relation between surface temperature and air temperature

With respect to the warming of the ground atmosphere layer, surface temperature should be higher than air temperature, or the two should be equal. The obtained results confirm this assumption only partially (Tab. 4).

The analysis of scenes from the year 2009 confirmed the theoretical assumption of lower air temperatures with the exception of that recorded on 27th Sept. at the BYST and DDHL stations. The number of cases where the surface temperature values in the surroundings of the stations in 2010 were lower than those at 1.5 m above the ground was incomparably higher. The situation occurred on 12th July and 22th Aug. on the stations BOT_PeF, DDHL and KOPE.

When assessing the level of surface and air temperatures by individual stations, then the surface temperature was always higher at stations ENVE, DOMI, JUTA and LETO. Lower surface temperature occurred in three cases at the stations BYST and DDHL.

As to the date of taking the thermal scene, the situation was more difficult. The always higher surface temperatures recorded on the measuring days at the stations BOT, DOMI, KOPE and LETO reflect characteristics of the surroundings of these stations where the active surface can be considered as homogeneous or consistent with the active surface in larger surroundings.

It is worth mentioning that on 28 Sept. when a higher surface temperature in the vicinity of all stations was recorded, the object of the analysis was the ASTER thermal image with a higher spatial resolution (90 m).

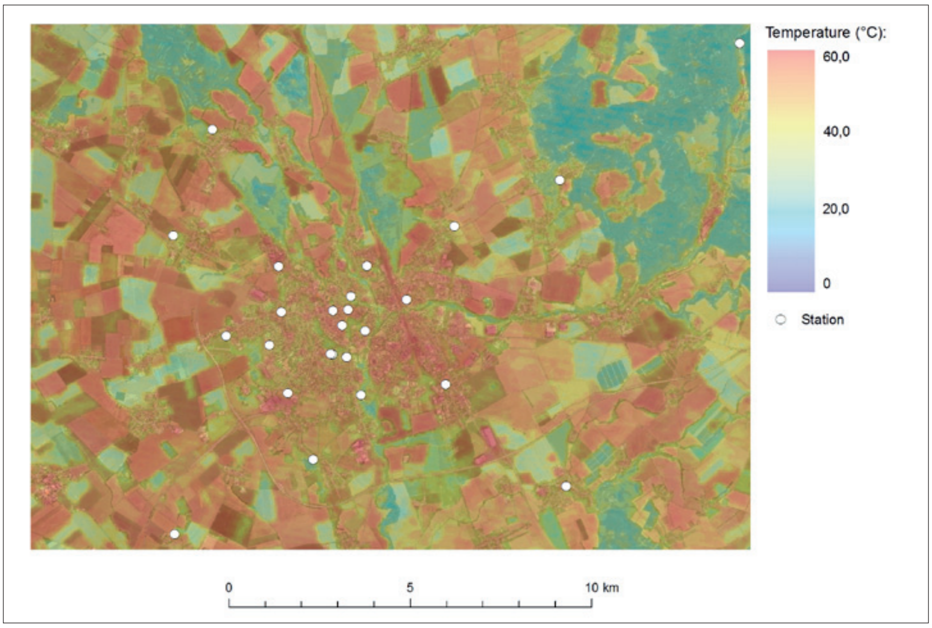

Fig. 10: Surface temperature field in Olomouc and its surroundings on 22th Aug. 2010 (source LANDSAT TM)

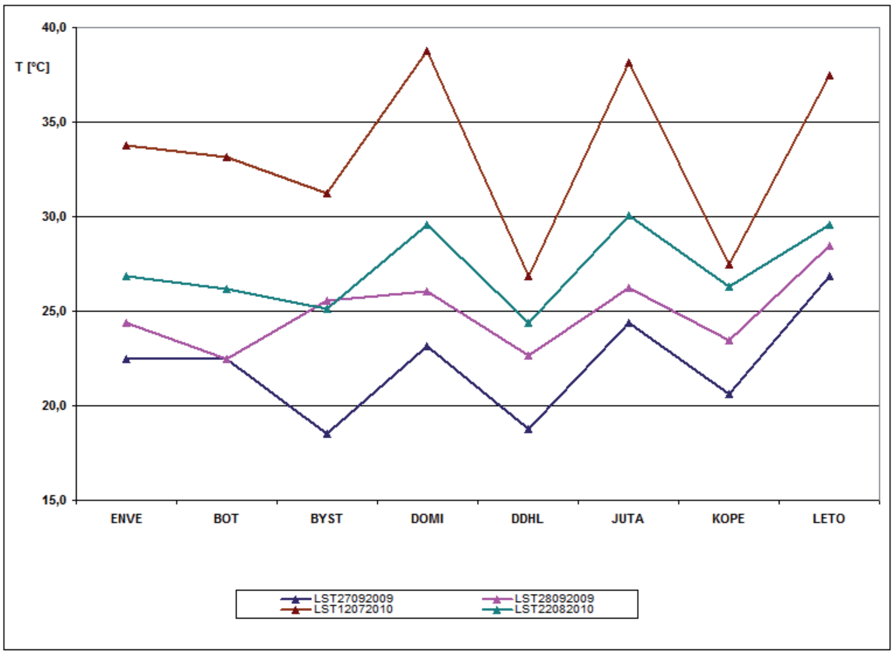

Fig. 11: Surface temperature (LST °C) in the surroundings of the selected MESSO stations, determined from ASTER satellite thermal images (LST22082010) and LANDSAT TM (LST27092009, and LST28092009 LST20072010)

Lower surface temperatures characterize at all times surroundings of the stations BOT-PeF, BYST, DDHL and KOPE. The reason may have to do with the location of the stations and namely with the character of the active surface. Both factors may be the reason why the surface was not sufficiently warmed up in the morning under the radiation weather and immediately above it a very thin inversion layer could have developed.

This is why the air at 1.5 m above the ground could have been warmer than the ground surface itself. A certain role could have been also played by the 120 m spatial resolution of the scenes, where the inhomogeneous active surface might have affected the calculation.

The rate of dependence between air temperatures on 12th July 2010 and 22th August 2010 recorded at all stations is expressed by the correlation coefficient 0.5407; the level of dependency between the values of surface temperatures on the same days was expressed as 0.9041.

The rate of correlation between the value of difference (LST-AT) and LST 22th Aug. 2010 is expressed by 0.9236; for 12th July 2010 it was 0.7104, which can be considered as values statistically significant.

Station	27th Sept. 2009	28th Sept. 2009	12th July 2010	22th Aug. 2010
BOT_PeF	20.8	22.0	33.8	27.3
BYST	20.9	20.2	32.8	26.4
DOMI	22.1	21.8	34.2	27.4
DDHL	21.0	20.2	31.6	26.0
KOPE	20.6	21.3	33.3	27.2
LETO	20.3	20.6	32.1	26.2

Tab. 3: Air temperature (AT °C) on 27th Sept. 2009, 28th Sept. 2009, 12th July 2010 and 22th Aug. 2010 on the selected MESSO stations at the time when the thermal images were taken

Station	Date	AT	LST	LST-AT
ENVE	27. Sept. 2009*	x	22.50	x
	28. Sept. 2009*	x	24.39	x
	12. July 2010*	33.49	33.75	0.26
	22. Aug.2010**	25.11	26.83	1.72
BOT_PeF	27. Sept. 2009*	20.78	22.50	1.72
	28. Sept. 2009**	22.00	22.47	0.47
	12. July 2010*	33.83	33.12	– 0.71
	22. Aug. 2010*	27.29	26.17	– 1.12
BYST	27. Sept. 2009*	20.90	18.50	– 2.40
	28. Sept. 2009**	20.20	25.54	5.34
	12. July 2010*	32.80	31.25	– 1.55
	22. Aug. 2010*	26.36	25.12	– 1.24
DOMI	27. Sept. 2009*	22.12	23.12	1.00
	28. Sept. 2009**	21.79	26.07	4.28
	12. Kuůy .2010*	34.22	38.75	4.53
	22. Aug. 2010*	27.39	29.56	2.17
DDHL	27. Sept. 2009*	21.01	18.75	– 2.26
	28. Sept. 2009**	20.18	22.67	2.49
	12. July 2010*	31.57	26.87	– 4.70
	22. aug. 2010*	25.95	24.40	– 1.55
JUTA	27. Sept. 2009*	x	24.37	x
	28. Sept. 2009**	x	26.24	x
	12. July 2010*	33.80	38.12	4.32
	22. Aug. 2010*	27.40	30.04	2.64
KOPE	27. Sept. 2009*	20.58	20.63	0.05
	28. Sept. 2009**	21.30	23.43	2.13
	12. July 2010*	33.29	27.50	– 5.79
	22. Aug. 2010*	27.18	26.30	– 0.88
LETO	27. Sept. 2009*	20.28	26.86	6.58
	28. Sept. 2009**	20.56	28.47	7.91
	12. July 2010*	32.14	37.50	5.36
	22. Sept. 2010*	26.24	29.56	3,32

*Tab. 4: Air temperature (AT °C) at 1.5 m above ground surface on selected MESSO stations at the time of taking the images; surface temperature (LST °C) on thermal satellite images for the surroundings of these stations and their difference (LST-AT °C), (** ASTER, * LANDSAT TM, x - data were not available)*

4. Discussion and conclusion

The objectives of this research project concentrated on the analysis of the surface temperature field and its spatial differentiation in the urban and suburban landscapes of Olomouc from satellite thermal images. The available scenes made it possible to achieve this goal, even though the selection for the period 2009–2010 was very limited. A partial objective was to compare surface temperatures in the surroundings of selected MESSO stations with air temperatures at 1.5 m above the ground surface for these stations at the time when satellite scenes were taken. This part of the research, too, produced results which appeared to be complicated.

For the comparison of results from individual scenes, it is useful that the scenes were taken approximately at the same time. A less advantageous aspect is that the scenes were taken only in the months of July and August when the state of vegetation in its developmental stages very distinctly affects the possibility of the transformation of radiant solar energy to heat energy and the degree of its radiation into the ground layer of the atmosphere. This was probably one of the main reasons why the apparently most conclusive results were harvested from the scene taken on 12th July 2010.

Further interpretation of temperature field differences between the urban and suburban landscapes made use of air temperatures recorded by the MESSO stations at a height of 1.5 m above the active surface at the time when the satellite scenes were taken. This made it possible to assess causal local relations between surface and air temperatures. Not always and not at all stations the temperature stratification was unstable. Relatively often the surface exhibited temperatures lower than those of the adjacent ground-level atmosphere at 1.5 m above the ground. It turned out that active surface in the surroundings of the station plays a more important role than the type of the station (urban, suburban).

Based on the research results it can be stated that the applicability of commonly-available thermal satellite images for the description of temperature field differences between the urban and suburban landscapes of a medium-sized city is possible, with some limitations. The main limitation is the season of the year because the non-existence of green vegetation may give rise to heat islands (thermal spots) also in the suburban landscape (Fig. 7). In this sense, the effect of forest stands is very distinct as obvious from the analyzed scenes.

Another limitation is the spatial resolution of thermal satellite images. Evidence of this can be lower surface temperatures recorded in many cases on the LANDSAT scenes (120 m) as compared with air temperatures recorded on the meteorological stations. In case of the ASTER scene (90 m), surface temperatures in the surroundings of the MESSO stations were at all times higher than the corresponding air temperatures. The specification of warmer or colder areas from satellite thermal images appears only of informative character in the case of medium-sized cities. A more precise delimitation of these areas would be possible from aerial thermal images, terrestrial thermal monitoring or directly based on results of special-purpose meteorological measurements.

The above-characterized method of analyzing the spatial differentiation of temperature fields in urban and suburban landscapes is just one of several possible levels. Maps of surface temperature fields represent one of the usable outputs from a multilevel study of the urban and suburban climate of Olomouc, as a medium-sized city. The results achieved to date constitute a basis for subsequent studies of temperature regimes from special-purpose mobile or stationary meteorological measurements, possibly from terrestrial thermal monitoring.

Acknowledgement

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Satellite images:

LANDSAT: United States Geological Survey, http://glovis.usgs.gov

ASTER: ARCDATA PRAHA, s.r.o.

Authors' addresses:

Mgr. Jan GELETIČ, e-mail: *geletic.jan@gmail.com*
Assoc. Prof. RNDr. Miroslav VYSOUDIL, CSc., e-mail: *miroslav.vysoudil@upol.cz*
Palacky University Olomouc, Faculty of Science, Department of Geography
17. listopadu 12, 771 46 Olomouc, Czech Republic

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ENVIRONMENTAL FACTORS INFLUENCING THE SPECIES COMPOSITION OF ACIDOPHILOUS GRASSLAND PATCHES IN AGRICULTURAL LANDSCAPES

Petr HALAS

Abstract

The acidophilous grasslands of the south-western part of the Czech-Moravian Highlands in the Czech Republic were substantially reduced in the 20th century. These patches are addressed in this paper, in terms of the impacts of their size, isolation, and the quality of the surrounding land cover. Species recorded in the acidophilous grasslands are categorized by hemeroby and life form. Multivariate gradient analysis revealed that the greatest proportions of the variability of species data were explained by two local variables (soil pH and the shape of the patch). Some species groups were also substantially influenced by microrelief. The importance of the surrounding land cover for the species composition was studied by means of regression trees. An assumption that, aside from local factors (soil pH and micro-relief), the species composition is significantly influenced by the heterogeneity of the surrounding landscape, was confirmed.

Shrnutí

Faktory ovlivňující druhové složení ostrůvků acidofilních trávníků v zemědělské krajině

Acidofilní trávníky jihozápadní části Českomoravské vrchoviny byly ve 20. století výrazně redukovány. V této práci byly zjišťovány důsledky izolace, velikosti plochy ostrůvku a kvality okolního krajinného pokryvu na jejich druhové složení. Byly rozlišeny druhy zaznamenané v acidofilních trávnících podle hemerobie a životní formy. S pomocí mnohorozměrné gradientové analýzy bylo zjištěno, že z použitých lokálních proměnných vysvětlilo největší část variability druhových dat pH půdy, ale rovněž tvar ostrůvku, některé skupiny druhů jsou také výrazně ovlivněny mikroreliéfem. Význam okolního land cover na druhové složení byl analyzován s pomocí regresních stromů. Byl potvrzen předpoklad, že druhové složení je vedle lokálních faktorů jako jsou pH půdy nebo mikroreliéf významně ovlivňováno heterogenitou okolní krajiny.

Keywords: *acidophilous grasslands, hemeroby, patch isolation, patch area, regression trees, Bohemian-Moravian Highland, Czech Republic*

1. Introduction

The study of processes influencing the species composition in fragmented biotopes stems from the presumption of the validity of the island biogeography theory (MacArthur, Wilson, 1967). The application of this theory to fragmented biotopes in an anthropogenically altered landscape requires an approach including basic parameters such as size, shape, landform heterogeneity and isolation of the islands, as well as characteristics of the surrounding land cover. This article therefore summarises the biogeographical regularities of the appearance of certain plant species in the context of human influence on the landscape.

In the south-western part of the Bohemian-Moravian Highland, the landscape consisting of farmland and pure spruce woods of varying sizes, still contains fragments of acidophilous grassland in the form of very small patches enclosed within arable land. The fragmentation of the previously common acidophilous grasslands in the 20th century was associated with more intensive use of agricultural land and eutrophication of their surroundings; moreover, cattle grazing in the open, once widespread, ceased almost everywhere. In a regional context, the conservation value of these patches is not usually very high, although some of them still harbour rare plant species. The minute size of these acidophilous grassland patches led to their being somewhat neglected by scientists in the past. However, interest in acidophilous grassland patches has been recently revived in the light of a number of surprising findings of animal species, especially of relatively thermophilous insects (Křivan et al., 2009).

The disappearance of acidophilous vegetation habitats and heathlands, together with the widespread extension of meadowlands as part of the intensification of agriculture is evident in much of Europe (Pott, 1996; Mac Donald et al., 2000; Odé et al., 2001). More intensive agriculture leads to fragmentation and also to a larger degree of isolation of biotopes (Meffe, Caroll, 1997). The processes of fragmentation and isolation impair partial populations (Pimm et al., 1988). The species diversity of acidophilous grasslands is influenced by many factors: apart from the size and isolation of the island, which affect the rate of extinction and immigration (MacArthur, Wilson, 1967), these include namely local conditions and landscape context (Cousins et al., 2007).

2. Material and methods

2.1 Study area

The study was conducted in the south-western part of the Bohemian-Moravian Highland in the Czech Republic (Fig. 1). Total area containing the studied patches takes up approximately 4 km^2 and it is situated in the cadastral area of Matějovec (Jindřichův Hradec district). The area lies within the territory built of granite bedrock. In the past, acidophilous grasslands occurred here most frequently as linear vegetation along paths and roads, on balks, at forest margins, and still around bedrock outcrops. The elevation of the gently undulating study area ranges between 650 and 680 m a.s.l. Average total precipitation amount is 715 mm, average annual air temperature is 6.7 °C (Tolasz et al., 2007).

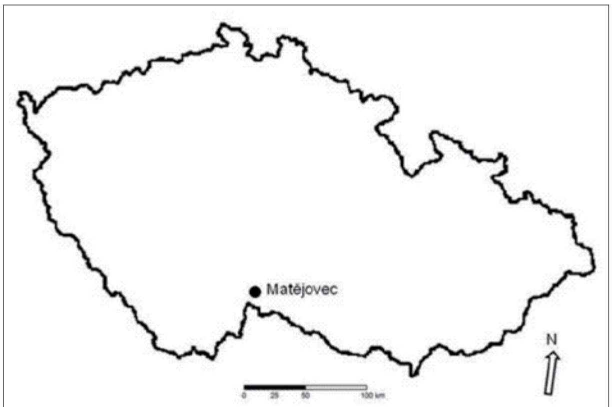

Fig. 1: Location of study area in the Czech Republic

2.2 Floristic and species data

The species composition of the vegetation studied may be categorized as that of acidophilous grasslands on shallow soils, submontane and montane Nardus grasslands, and secondary submontane and montane heaths (Chytrý et al., 2001). Acidophilous grasslands on shallow soils are low and open growths with dominating *Festuca ovina* or *Scleranthus perennis*, rarely also *Agrostis capillaris* or *A. vienalis* and *Hieracium pilosella*. Besides the dominant species, there are also some species of dry and poor soils such as *Hypericum perforatum*, *Jasione montana*, and *Lychnis viscaria*. The community occurs on acidic silicate rocks in uplands and mountain areas. Submontane and montane Nardus grasslands and secondary submontane and montane heaths are represented by growths of Nardus stricta and other grass species, e.g. *Agrostis capillaris*, *Danthonia decumbens*, *Festuca filiformis*, *F. ovina* and *F. rubra agg.*, accompanied by herbs such as *Galium pumilum*, *G. saxatile*, *Polygala vulgaris*, and *Viola canina*. The habitat includes mixed herbaceous and grass stands of both rich and poor species varieties differentiated by the soil nutrient content (Chytrý et al., 2001).

The individual patches often create mosaic or transition patterns, which are simplified as acidophilous grasslands for the purposes of this paper. A total of 35 patches were addressed, of which only 21 were selected for this paper, all of them isolated from the surrounding area either by arable land or wetland. A total of 54 phytosociological relevés were included. The non-included patches were situated within degraded areas of acidophilous grassland or had a higher share of woody plants. On each patch, three relevés were made sized 2 × 2 m, located where possible at the southern and northern edges and in the central part. All higher plant species within the patch were recorded, while the same was done for deliberately-laced phytosociological plots. The occurrence of vascular plants was quantified using the nine-degree Braun-Blanquet abundance and dominance scale (Westhoff, van der Maarel, 1978). In total, 89 species of vascular plants were recorded on 21 patches, and were divided into groups by hemeroby, life form, and origin; these groups were analysed separately.

In terms of hemeroby, the species groups were defined by means of the Biolflor database (Klotz et al., 2003). The selection was simplified to three groups

1. oligohemerobic plant species, which also covered some ahemerobic plant species,
2. mesohemerobic plant species, and
3. b-euhemerobic plant species, also covering some c-euhemerobic and polyhemerobic plant species.

Oligohemerobic plant species occur in habitats that are less influenced by human activity, e.g. in occasionally used woodlands, semi-natural moorlands and dry grasslands; examples of oligohemerobic plant species in the acidophilous grasslands studied are *Calluna vulgaris*, *Festuca filiformis*, *Jasione montana* or *Scleranthus perennis*. Mesohemerobic plant species occur in woodlands with native species composition and on more species-diverse meadows with more intensive use; examples of mesohemerobic plant species on the patches studied include the previous oligohemerobic plant species accompanied by a number of species that can withstand higher anthropogenic pressure, e.g. *Ranunculus acris*, *Rumex acetosa* or T*rifolium aureum*. The b-euhemerobic plant species group, which also included the c-euhemerobic and polyhemerobic species, consists of those species that occur in habitats substantially altered by humans, such as ruderal habitats or forest monocultures (Klotz et al., 2003). Species of the most impacted habitats include e.g. *Arrhenatherum elatius*, *Holcus mollis*, *Galeopsis pubescen*. All the recorded species, including hemeroby and life form categories, are listed in Supplement 1.

In terms of life forms, only oligohemerobic chamaephytes and nanophanerophytes were recognised in accordance with Kubát et al. (2002). The number of species in the relevant categories was understood as the proportion of their classification in the given category, i.e. a species belonging in two categories (e.g. ahemerobic and oligohemerobic at the same time) was rated as 0.5.

2.3 Patch and land cover characteristics

All acidophilous grassland patches were vectorized, including 600 m of their surroundings, using ArcGIS8.3 (www.esri.com). Seven types of land cover were differentiated: acidophilous grassland, broadleaved woods, coniferous woods, wetlands, fields and ruderal vegetation, meadows and settlements. Land area was defined for all segments, followed by the calculation of their shares, lengths of boundary, number of segments, numbers of land cover type in the buffer zones surrounding each of the patches at a distance of 25 m, 50 m, 75 m, 100 m, 200 m, 300 m, and 600 m. One of the methods used for expressing landscape heterogeneity was the Shannon-Wiewer index (Pielou, 1966) calculated from the land cover quotient in the buffer zones:

$$H' = -\sum [(n_i/n)\ ln(n_i/n)]$$

where "n_i" is the share of land cover types, "n" is the number of land cover types.

The shape of the patch was defined using the *P*/*A* ratio (where *P* is circumference, *A* total area) and two indexes:

$$S = P\ /\ (2\sqrt{A}\ \pi),$$ (Faeth, Kane, 1978)

where *P* is the circumference and *A* the total area, the index reaches higher values with the increasing divergence of the woodland patch from the circular shape;

$$Frac = 2 \times lnP\ /\ lnA,$$ (De Sanctis et al., 2010)

where *P* is the circumference and *A* the total area, the index value oscillates between 1 (regular shape) and 2 (irregular shape).

The ratios of land cover units at selected distances were weighted by three coefficient alternatives (Tab. 1) and added up to produce a variable expression of the meaning of differently distant land cover categories. The size of acidophilous patches ranged between 41 m^2 and 503 m^2 (mean 225 m^2). The irregularity of patches represented by indexes *P*/*A*, *S* and *Frac* ranged between 0.18 and 0.58 (P/A, mean 0.33), betwen 0.12 and 0.21 (S, mean 0.16) and between 1.31 and 1.45 (Frac, mean 1.38).

In addition to the variables produced by ArcGIS – area, circumference, *S*, *Frac*, and *P*/*A* – active soil pH, rock cover, inclination, index radiation and head (McCune, Keon, 2002), elevation above the surrounding terrain, and position of the phytosociological relevé within the patch were incorporated for the analysis.

2.4 Data analysis

Normality of the data was examined by means of STATISTICA 8.0 software (Statsoft Inc., 2000) and the Shapiro-Wilk W test. The abnormal

Distances (m)	0–25	26–50	51–75	76–100	101–200	201–300	301–600
w1	1.07	1.03	1.00	0.90	0.80	0.70	0.60
w2	1.14	1.07	1.00	0.80	0.60	0.40	0.20
w3	1.20	1.10	1.00	0.70	0.40	0.10	0.00

Tab. 1: Coefficients for weighting the ratio of land cover units at various distances

distribution of most data dictated the use of non-parametric methods. The species composition for multi-component analyses were logarithmically transformed using Hill scaling and considering the long gradient (over 3.0 SDU). In most of the species groups, the canonical correspondence analysis (CCA) was used in line with the recommendations of ter Braak and Šmilauer, 2005. Statistical significance was determined by the Monte Carlo permutation test (999 permutations).

To investigate the relation between the ratio of selected species groups in the phytosociological relevés and all recorded variables including landscape characteristics, we used the method of creating regression trees (Breiman et al., 1984; De'ath, Fabricius, 2000) in Statistica 8.0 software (Statsoft Inc., 2000).

In the graphic representation of the trees, each node is characterised by a value explaining the variables used for the relevant division, average share of species in the node with a standard deviation and the number of relevés falling into that node. The optimal tree was selected using 10-fold cross-validation, with the analysis being repeated on 10 randomly selected sub-files, and one tree with a minimum value of explained variability of the validation data was selected from the resulting trees with the adjustment of Standard Error rule = 0. Four surrogates were calculated for each of the trees, which provide divisions as close as possible to the primarily selected factor. In the results, they are shown under the values of the explanatory variable and only if their associative value was > 0.50. The shares of species processed in regression trees were derived only from the numbers of herbaceous plants.

3. Results

3.1 Multivariate analyses

The analysis of phytosociological relevés taken within the fragment of a biotope of the known size may be used to determine whether the influence of the size and shape of that fragment reflects in the species composition even over the area of a constant size.

The variable that proved most important for the diversity of the species composition of phytosociological relevés was soil pH the significance of which is the highest in the species bound to acidophilous grasslands and lower in the groups of species bound to other biotopes (Tab. 2). Size and circumference did not play a significant role in any of the defined groups, while the shape characteristics of the patch significantly showed in all groups of the species at a level of the phytosociological relevés. In the oligohemerobic group, the variability of the species composition was affected also by the position of the phytosociological relevé within the patch.

	Oligohemerobic			**Mesohemerobic**			**B-euhemerobic**			**Oligohemerobic chamaephytes and nanophanerophytes**		
	var. (%)	F	P	var. (%)	F	P	var. (%)	F	P	var. (%)	F	P
Soil pH	8,6	4,772	≤0.001	7,1	3,982	≤0.001	4,2	2,282	≤0.001	14,7	8,109	≤0.001
Slope	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
Radiation	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
Heat	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
Shell	2,8	1,645	0,042	-	-	n.s.	-	-	n.s.	5,6	3,627	0,006
Area	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
Circumference	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
P/A	4,0	2,320	0,003	3,7	2,109	0,004	2,9	1,605	0,038	3,8	2,502	0,034
S	-	-	n.s.	-	-	n.s.	-	-	n.s.	6,3	3,621	0,008
Frac	-	-	n.s.	2,7	1,537	0,046	-	-	n.s.	4,6	2,840	0,014
South	3,1	1,812	0,022	-	-	n.s.	-	-	n.s.	5,4	3,082	0,020
Middle	1,6	-	-	-	-	n.s.	-	-	n.s.	1,6	-	-
North	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
Elevation	-	-	n.s.	-	-	n.s.	-	-	n.s.	-	-	n.s.
Σ	**20,1**	**-**	**-**	**13,5**	**-**	**-**	**7,1**	**-**	**-**	**42,0**	**-**	**-**

Tab. 2: Results of canonical correspondence analysis. Selected species groups were analysed using the forward selection method; Var. (%) – explained variability, F – value of test, P – statistical significance level, n.s. – not significant

The number of b-euhemerobic species and non-indigenous species positively correlates with soil pH values while the number of chamaephytes and nanophanerophytes negatively correlates with the soil pH (Tab. 3). The higher pH also eliminates the share of species characteristic of acidophilous grasslands – oligohemerobic, chamaephytes, and nanophanerophytes (Tab. 4).

The share of skeleton on the phytosociological relevé area reduces the diversity of oligohemerobic and mesohemerobic species and in contrast increases the proportion of non-indigenous species (Tabs. 3, 4). Patch area was the most important factor for the number of mesohemerobic and oligohemerobic species and on the other hand, it had no significant influence on the number of b-euhemerobic and non-indigenous species (Tab. 3, Figs. 2, 3). Patch shape significantly influenced the groups of species typical for acidophilous grasslands and was positively correlated with the number of oligohemerobic and mesohemerobic species, chamaephytes, and nanophanerophytes, i.e. the more irregular and elongated the patch, the lower the diversity of these species (Tab. 3, Figs. 4, 5, 6). A similar situation was also seen in the proportions of these species where the irregular shape correlated positively with the share of the b-euhemerobic species (Tab. 4).

The position of the phytosociological relevé significantly influenced only chamaephytes and nanophanerophytes, with their numbers and shares correlating positively with the position in the patch centre (Tabs. 3, 4).

Difference in elevation positively correlated with the numbers and shares of oligohemerobic and mesohemerobic species, as well as chamaephytes and nanophanerophytes (Tab. 4). The numbers and share of b-euhemerobic species decreased significantly with the increasing difference in elevation (Tabs. 3, 4).

3.2 Regression trees

The regression tree demonstrating the share of oligohemerobic species formed six end nodes and explained 26.4% of data variability (Fig. 7). The first

	Oligohemerobic	Mesohemerobic	B-euhemerobic	Oligohemerobic and chamaephytes and nanophanerophytes
Soil pH	n.s.	n.s.	0.54***	–0.29*
Slope	n.s.	n.s.	n.s.	n.s.
Radiation	n.s.	n.s.	n.s.	n.s.
Heat	n.s.	n.s.	n.s.	n.s.
Shell	n.s.	n.s.	n.s.	n.s.
Area	0.32*	0.45***	n.s.	n.s.
Circumference	n.s.	0.36**	n.s.	n.s.
P/A	–0.32*	–0.43**	n.s.	n.s.
S	–0.32*	–0.43**	n.s.	n.s.
Frac	n.s.	n.s.	n.s.	–0.27*
South	n.s.	n.s.	n.s.	n.s.
Middle	n.s.	n.s.	n.s.	n.s.
North	n.s.	n.s.	n.s.	–0.29*
Elevation	0.35**	n.s.	–0.51***	n.s.

*Tab. 3: Spearman's correlation of environmental variables with the numbers of species of the defined groups Significance levels: *P < 0.05, **P < 0.01, ***P < 0.001; n.s. not significant*

	Oligohemerobic	Mesohemerobic	B-euhemerobic	Oligohemerobic and chamaephytes and nanophanerophytes
Soil pH	–0.48***	–0.35	0.45***	–0.48***
Slope	n.s.	n.s.	n.s.	n.s.
Radiation	n.s.	n.s.	n.s.	n.s.
Heat	n.s.	n.s.	n.s.	n.s.
Shell	n.s.	-0.30*	n.s.	n.s.
Area	n.s.	0.29*	n.s.	n.s.
Circumference	n.s.	n.s.	n.s.	n.s.
P/A	n.s.	–0.30*	0.28*	n.s.
S	n.s.	–0.30*	0.28*	n.s.
Frac	–0.27*	n.s.	n.s.	–0.33*
South	n.s.	n.s.	n.s.	n.s.
Middle	n.s.	n.s.	n.s.	0.33*
North	n.s.	n.s.	n.s.	n.s.
Elevation	0.55***	0.41**	–0.54***	0.30*

*Tab. 4: Spearman's correlation of environmental variables with the share of species of the defined groups Significance levels: *P < 0.05, **P < 0.01, ***P < 0.001; n.s. not significant*

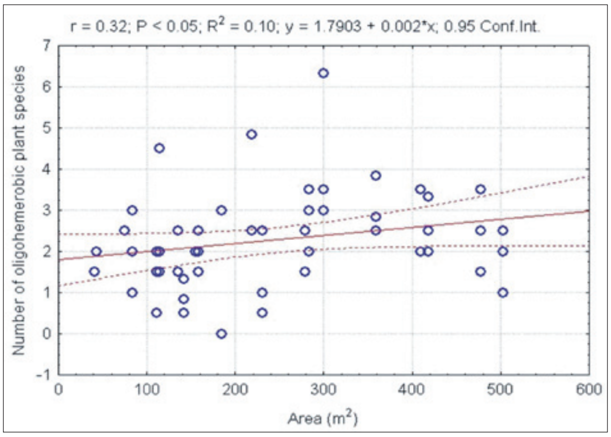

Fig. 2: *Relation between the number of oligohemerobic plant species in the phytosociological relevé and the patch area*

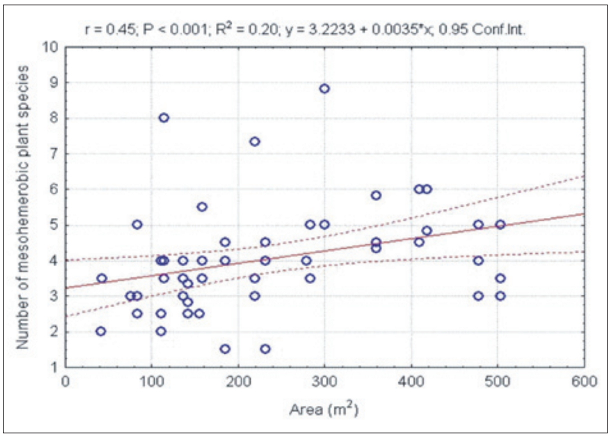

Fig. 3: *Relation between the number of mesohemerobic plant species in the phytosociological relevé and the patch area*

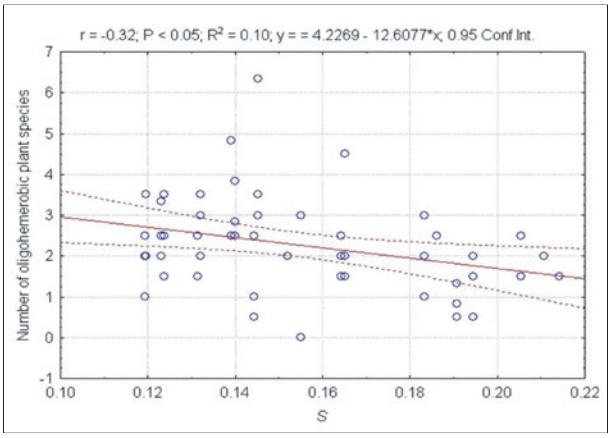

Fig. 4: *Relation between the number of oligohemerobic plant species in the phytosociological relevé and the patch shape index*

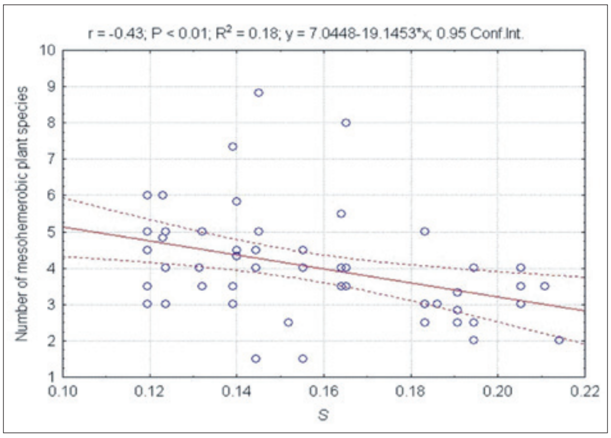

Fig. 5: *Relation between the number of mesohemerobic plant species in the phytosociological relevé and the patch shape index*

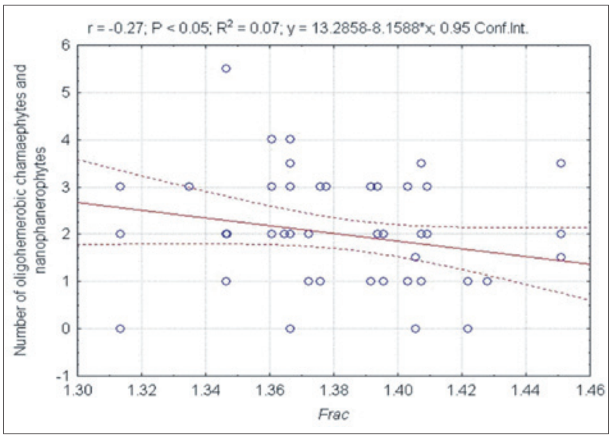

Fig. 6: *Relation between the number of oligohemerobic chamaephytes and nanophanerophytes in the phytosociological relevé and the patch shape index*

branching of the regression tree (1) is made according to the variable of phytosociological relevé elevation above the surrounding terrain; the higher share of oligohemerobic species is in the phytosociological relevés located higher above the surrounding terrain.

The group of phytosociological relevés with the lower ratio of oligohemerobic species was further divided into categories according to the extent of forest-free area boundaries (combined meadow and field segments) within a radius of 200 m where a higher ratio of oligohemerobic species was found in the group with higher heterogeneity of the forest-free area (5). The higher heterogeneity of the forest-free area also corresponded with generally higher heterogeneity given by the total length of all boundaries; moreover, the surroundings of these phytosociological relevés contained fewer forest-free areas (meadows, fields, acidophilous grasslands) than the other group (4). The group of phytosociological relevés with the higher ratio of oligohemerobic species (5) was further categorized by the proportion of meadows within a radius of 600 m. Higher shares of oligohemerobic species were found in the group (9) with more meadows in the surroundings and with higher heterogeneity of meadows and forest-free areas (meadows and fields) within a radius of 100 m and 200 m. The group of phytosociological relevés

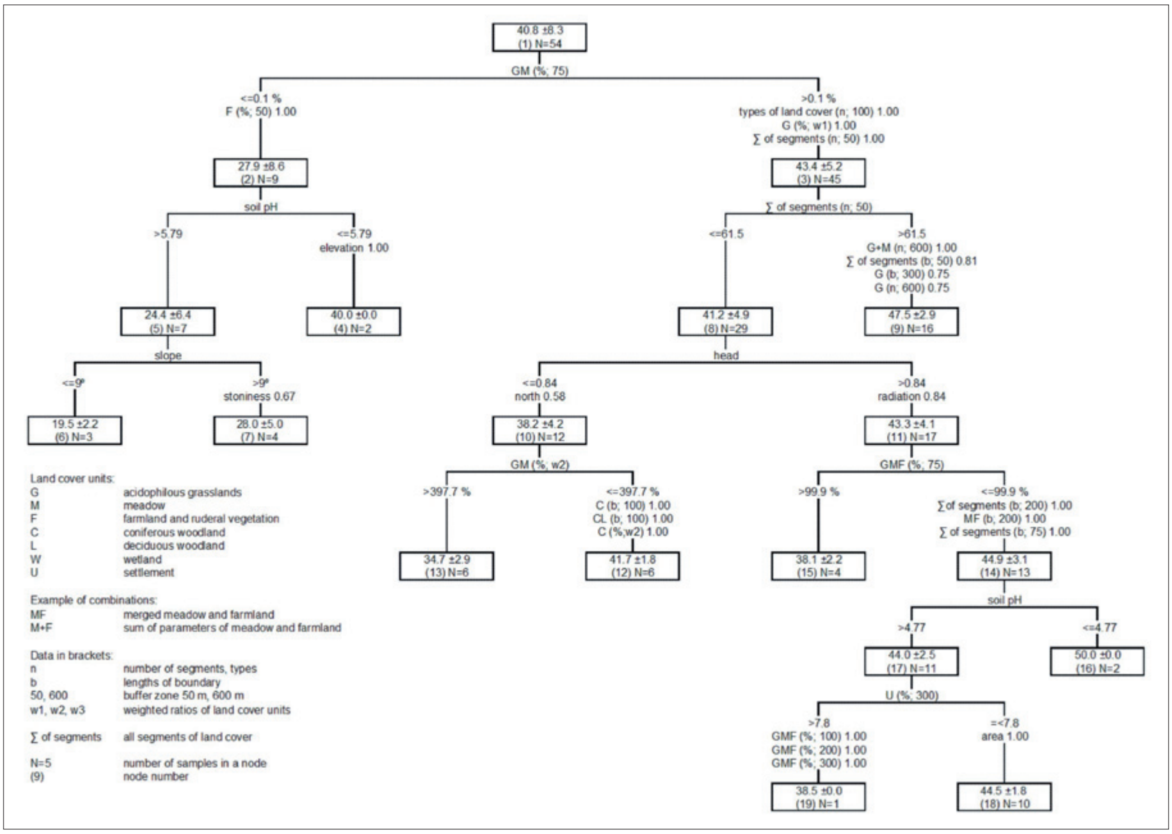

Fig. 7: Regression tree explaining the proportion of oligohemerobic plants in the phytosociological relevés. Each dichotomic division is characterised by a variable separating two homogeneous groups of phytosociological relevés, i.e. two nodes. Each node (its number stated in brackets) is accompanied by the value of the variable that has lead to its separation and is characterised by the average ± standard deviation of the share of oligohemerobic species therein and the number of phytosociological relevés belonging thereto. Under the variable values are marked the so-called surrogates providing the division of the most similar variable used in the particular branching. Surrogates are situated on that side of the dichotomic branching on which they gain higher values with their associative value being stated at the end.

(3) with the higher representation of oligohemerobic species in the relatively highest parts of the patches was further divided according to the share of acidophilous grasslands within a radius of 600m; higher proportions of oligohemerobic species were found in phytosociological relevés with a greater share of acidophilous grasslands within a radius of 600 m. The group of phytosociological relevés in the node (22) was further divided according to the radiation index; a higher proportion of oligohemerobic species was found in the relatively more irradiated relevés.

The regression tree demonstrating the representation of mesohemerobic species revealed 11 end nodes and explained 11.3% of data variability (Fig. 8). The first division was made according to the share of acidophilous grasslands and meadows within a boundary radius of 75 m. The proportion of mesohemerobic species was higher in phytosociological relevés that had a higher share of acidophilous grasslands and meadows in their surroundings; apparently, mere tenths of the per cent of these habitats make a difference. At the same time, the surroundings of these relevés showed a higher heterogeneity within a boundary radius of 50 m, expressed by the number of land cover segments, and a more diverse land cover within a 100 m radius.

The group of relevés with a lower share of mesohemerobic species (2) was subsequently divided according to soil pH values; relevés with higher soil pH values had a smaller proportion of mesohemerobic species. This group was divided once more according to the slope gradient; the group of relevés with a greater slope gradient (> 9°) exhibited a greater share of mesohemerobic species. The group of relevés with a higher proportion of mesohemerobic species (3) generated during the first division was further split according to the number of land cover segments within a boundary radius of 50 m; phytosociological relevés (9) with the higher heterogeneity of surroundings expressed by a larger number of land cover segments had a greater share of mesohemerobic species. The group of relevés (8) with less heterogeneous surroundings was divided according to the head index. Less insolated relevés exhibited a lower share of the mesohemerobic

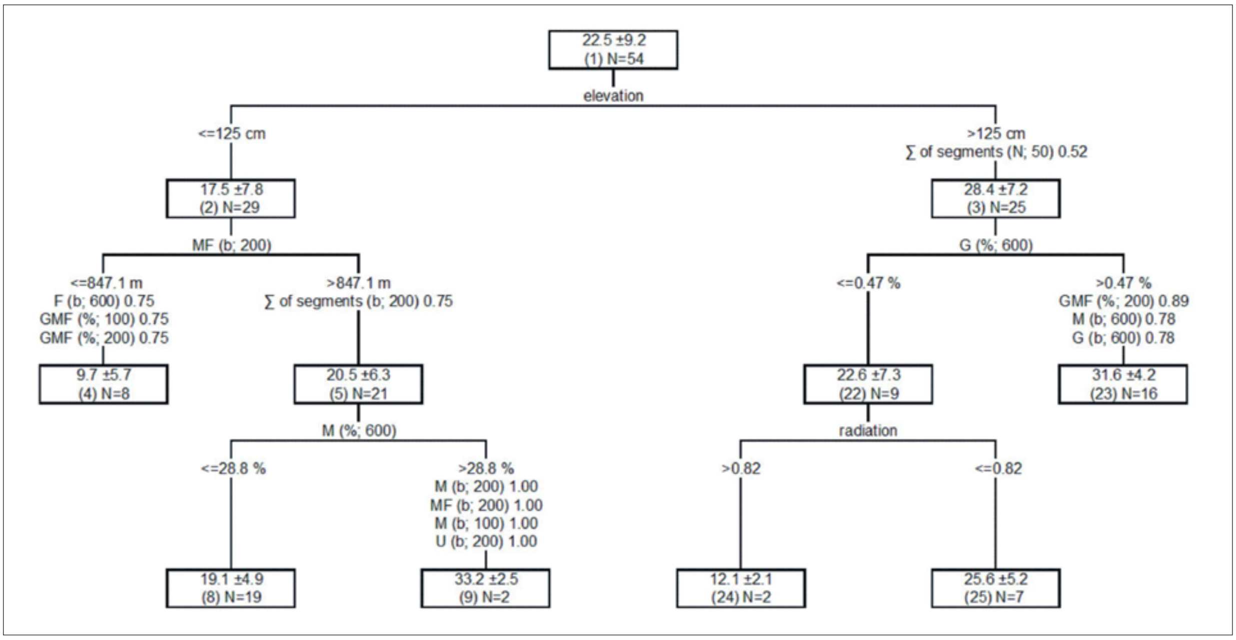

Fig. 8: Regression tree explaining the proportion of mesohemerobic plants in the phytosociological relevé. For explanatory description and legend see Fig. 7

species. The subsequent division split this group (10) according to the weighted values of forest-free areas (meadows and fields), i.e. the phytosociological relevés with closer and larger forest-free areas in their surroundings showed a lower share of mesohemerobic species. Relevés with higher head values (node 11) were divided according to the proportion of forest-free areas (acidophilous grasslands, meadows, fields) within a radius of 75 m. Patches entirely isolated within forest-free areas had a lower proportion of the mesohemerobic species. The group with more abundant mesohemerobic species (14) was further divided according to soil pH values; higher shares of mesohemerobic species were found in relevés with pH values > 4.76. The group of relevés (17) was further divided according to the area of settlements within a radius of 300 m; higher proportions of mesohemerobic species were detected in relevés with lower shares of settlements in their surroundings.

The regression tree demonstrating the ratio of b-euhemerobic species revealed three end nodes, explaining 43.8% of data variability (Fig. 9). In the first step, the regression tree was divided according to the proportion of fields within a radius of 50 m; phytosociological relevés almost entirely isolated in arable land had a higher share of b-euhemerobic species. The group of phytosociological relevés with

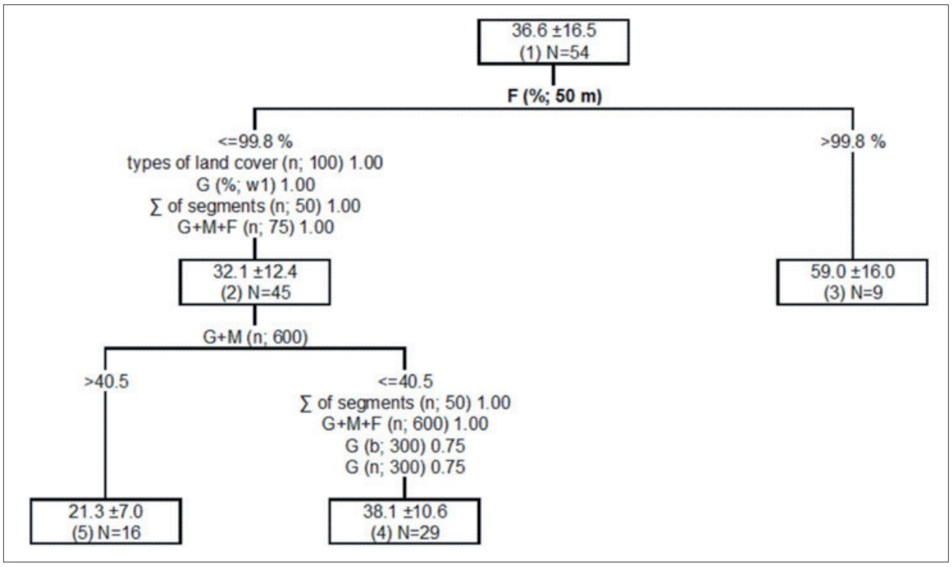

Fig. 9: Regression tree explaining the proportion of b-euhemerobic plants in the phytosociological relevé. For explanatory description and legend see Fig. 7

the lower share of b-euhemerobic species was divided once more, this time by the number of acidophilous grassland and meadow segments within a radius of 600 m. This group (5) showed a higher proportion of these permanent crops within a surrounding radius of 600 m and at the same time a substantially lower share of b-euhemerobic species.

4. Discussion

The size of the patch has a positive influence on the number of species within the patch; similar conclusions were also drawn by Kohn and Walsh (1994), who studied maritime islands in Great Britain, and Pärtel and Zobel (1999), Krauss et al. (2004), Öster et al. (2007), who worked on fragmented grasslands. In relation to the island biogeography theory (MacArthur and Wilson, 1967), this phenomenon may be explained by the higher number of habitats on larger islands. The significant relation between the number of species within one phytosociological relevé and the size of the island may have two causes that act simultaneously.

In the analysed species groups, there was a significant relation between the size of the patch and the number of species only in the oligohemerobic and mesohemerobic species groups, i.e. the groups that are most characteristic of acidophilous grasslands and heathlands. This could be explained by the saturation of the habitat as well as by the differences between generalist and specialist species. Foster et al. (2004) maintain that the species diversity of poor communities is limited by the number of available diasporas, whereas on more productive sites competition plays a much more important role. The stronger relation between the oligohemerobic and mesohemerobic species may also be explained by the characteristics of specialists, which are more limited by the size of the patch, while generalists also find their diaspora sources in the surrounding landscape (Krauss et al., 2004).

The division of species in the phytosociological relevés into three groups by hemeroby was important for distinguishing the species characteristic of acidophilous grasslands and heathlands (oligohemerobic), and less specialised (mesohemerobic) species from the species entirely allochthonous for these habitats (b-euhemerobic).

These three groups of species may also be used as indicator tools for investigating the relation of species composition with the character of the surrounding landscape. As the canonical correspondence analysis shows (Tab. 2), of all analyzed groups, the variability of oligohemerobic species composition is most influenced by the soil pH and by the patch shape, immediately after the specific group of oligohemerobic chamaephytes and nanophanerophytes, whereas in b-euhemerobic species this situation is reversed. We may assume that most of the recorded oligohemerobic species, oligohemerobic chamaephytes and nanophanerophytes within the studied area are currently bound to the remnants of the acidophilous grasslands and largely include specialized species with a competitive advantage on acidic and poor soils. B-euhemerobic species include a number of ruderal species that are quite common on arable land or on abandoned agricultural areas. Their occurrence in acidophilous grasslands may be limited by the low soil pH or by the low availability of nutrients while their broad distribution in the contemporary landscape clearly indicates that they are not limited by the patch size. Mesohemerobic species have a transient position according to the values of explained variability of species composition with the soil pH and patch shape. Differences between the above characterized species groups may therefore be explained by the "specialist and generalist concept" (Kraus et al., 2004).

The results of multivariate analysis are further complemented by correlations between the species number and abundance. The number of oligohemerobic and mesohemerobic species positively correlates with the area size of the patch, and for mesohemerobic species this relation is even more significant ($r = 0.45$; $p < 0.001$) compared to oligohemerobic species ($r = 0.32$; $p < 0.05$). Mesohemerobic species constitute the most abundant group of species present in all the patches studied while oligohemerobic species were not recorded in the phytosociological plots from some patches. Apart from the area size, there are other factors that significantly influence the occurrence of oligohemerobic species, e.g. the degree of influence expressed by a positive correlation of species numbers with the increasing elevation above the surrounding terrain. Both the numbers and the proportions of oligohemerobic chamaephytes, nanophanerophytes, as well as mesohemerobic species, correlate with the shape of the patch. With the increasing irregularity of the patch shape, the number and proportion of these species would decrease. B-euhemerobis species significantly positively correlate with the tortuousness of the patch shape. The patches of acidophilous grasslands are more influenced by the supply of b-euhemerobic species diasporas the greater is their contact area with their surroundings. B-euhemerobic species are thus more limited in patches of circular shape and with relatively high super-elevation; the opposite holds for oligohemerobic species.

The results of the regression trees demonstrate that the most important predictor for the diversity of oligohemerobic species in the set of the phytosociological relevés used is the elevation of the image area above the surrounding terrain. Higher situated parts of acidophilous grasslands are better protected from impacts threatening the oligohemerobic species. Other important predictors for a higher proportion of oligohemerobic species include the higher heterogeneity of the surrounding landscape and the higher share of meadows which, unlike other land cover types, may host more species common with the acidophilous grasslands. The most important predictor of the higher occurrence of mesohemerobic

Species	Life form	Hemeroby			Species	Life form	Hemeroby	
Quercus robur	MFf	o	m	-	*Cerastium arvense*	Chf	m	b
Holcus lanatus	Hkf	o	m	-	*Lathyrus pratensis*	Hkf	m	b
Prunus avium	MFf	o	m	-	*Rubus idaeus*	NFf	m	b
Fragaria vesca	Hkf	o	m	-	*Hieracium pilosella*	Hkf	m	b
Hieracium laevigatum	Hkf	o	m	-	*Stellaria graminea*	Hkf	m	b
Lychnis viscaria	Hkf	o	m	-	*Agrostis capillaris*	Hkf	m	b
Potentilla tabernaemontani	Hkf	o	m	-	*Holcus mollis*	Gf	m	b
Frangula alnus	NFf	o	m	-	*Arrhenatherum elatius*	Hkf	m	b
Dianthus deltoides	Tf	o	m	-	*Carex ovalis*	Hkf	m	
Scleranthus perennis	Hkf	o	m	-	*Apera spica-venti*	Tf	-	b
Carex caryophyllea	Hkf	o	m	-	*Cirsium vulgare*	Tf	-	b
Veronica officinalis	Chf	o	m	-	*Rubus caesius*	Chf	-	b
Pteridium aquilinum	Gf	o	m	-	*Scleranthus annuus*	Tf	-	b
Hieracium lachenalii	Hkf	o	m	-	*Taraxacum sect. Ruderalia*	Hkf	-	b
Solidago virgaurea	Hkf	o	m	-	*Epilobium angustifolium*	Hkf	-	b
Campanula rotundifolia	Hkf	o	m	-	*Galeopsis tetrahit agg.*	Tf	-	b
Festuca filiformis	Hkf	o	m	-	*Sonchus arvensis*	Hkf	-	b
Potentilla erecta	Hkf	o	m	-	*Vicia hirsuta*	Tf	-	b
Polygonatum odoratum	Gf	o	m	-	*Poa supina*	Hkf	-	b
Thymus pulegioides	Chf	o	m	-	*Senecio viscosus*	Tf	-	b
Galium pumilum	Hkf	o	m	-	*Arabidopsis thaliana*	Tf	-	b
Genista tinctoria	NFf	o	m	-	*Myosotis arvensis*	Tf	-	b
Calluna vulgaris	Chf	o	m	-	*Veronica arvensis*	Tf	-	b
Vaccinium myrtillus	Chf	o	m	-	*Vicia angustifolia*	Tf	-	b
Avenella flexuosa	Hkf	o	m	-	*Cirsium arvense*	Hkf	-	b
Sorbus aucuparia	MFf, NFf	o	m	b	*Acer pseudoplatanus*	MFf	-	b
Geranium pusillum	Tf	-	m	b	*Galium aparine*	Tf	-	b
Nardus stricta	Hkf	-	m	b	*Viola arvensis*	Tf	-	b
Ranunculus acris	Hkf	-	m	b	*Urtica dioica*	Hkf	-	b
Hieracium murorum	Hkf	-	m	b	*Linaria vulgaris*	Hkf	-	b
Vicia cracca	Hkf	-	m	b	*Galeopsis pubescens*	Tf	-	b
Rumex acetosa	Hkf	-	m	b	*Galium album*	Hkf	-	b
Lathyrus sylvestris	Hkf	-	m	b	*Hypericum perforatum*	Hkf	-	b
Hylotelephium maximum	Hkf	-	m	b	*Picea abies*	MFf	-	b
Phleum pratense	Hkf	-	m	b	*Brassica napus*	Tf	-	b
Trifolium aureum	Hkf	-	m	b	*Fallopia convolvulus*	Tf	-	b
Veronica chamaedrys	Hkf	-	m	b	*Anthemis cotula*	Tf	-	b

Supplement 1: The List of all recorded vascular plant species with categories of hemeroby and life form. Life forms: MFf – macrophanerophyte, NFf – nanophanerophyte, Hkf – hemicryptophyte, Tf – therophyte, Chf – chamaephyte, Gf – geophyte,; hemeroby: o – oligohemerobic, ahemerobic, m –mesohemerobic, b – b-euhemerobic, c-euhemerobic and polyhemerobic

species is a greater share of acidophilous grasslands and meadows. Similarly as in the oligohemerobic species, the occurrence of mesohemerobic species would increase with higher heterogeneity of the ambient environment but also with higher extremity of the habitat expressed for example by greater slope gradient or values of radiation and head index.

The most significant predictor of the occurrence of b-euhemerobic species is the share of arable land in the immediate surroundings. The results of the regression trees suggest how essentially important are characteristics of the surrounding landscape in addition to local variables. The results providing regression trees support a stronger relation of the species composition of narrower species groups to local conditions, illustrating also the key importance of the landscape context. Cousins et al. (2007) studied the effect of the landscape context on the species composition, too and found out that species diversity correlated with the percentage share of the same habitat within a radius of 1,000 m. Rogers et al. (2009) also came to similar conclusions when they studied the extinction of species in the undergrowth of fragmented woodlands, highlighting a greater importance for the landscape context compared to the conventionally-used local environment variables. In the regression analysis, characteristics from the 600-m surroundings were applied; we therefore assume that the influence on the species composition of the studied patches does not cease at this distance.

5. Conclusion

The results of this work show that the species composition of fragmented vegetation complies with the principles of the island biogeography theory (MacArthur and Wilson, 1967), and depends on the surrounding land cover in both local and greater landscape contexts. The context of the surrounding landscape on the species composition may have a greater influence for some groups of species than the variable environment that is conventionally used in vegetation studies. The size and shape of the patch is more important for the characteristic species of the acidophilous grasslands, while the number of species typical for habitats under strong anthropogenic influence depends more on the quality of the surrounding landscape. The protection of the acidophilous grassland patches studied should therefore include at least partial re-establishment of historic farming methods – grazing and cutting as well as a more considerate use of their close surroundings.

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Authors´ address:

Mgr. Petr HALAS, Ph.D.
Institute of Geonics of the AS CR, v.v.i., Brno branch
Drobného 28, 602 00 Brno, Czech Republic
e-mail: *halas@geonika.cz*

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LONG-TERM LAND USE DEVELOPMENT AND CHANGES IN STREAMS OF THE KYJOVKA, SVRATKA AND VELIČKA RIVER BASINS (CZECH REPUBLIC)

Marek HAVLÍČEK, Barbora KREJČÍKOVÁ, Zdeněk CHRUDINA, Josef SVOBODA

Abstract

The analysis and assessment of land use changes and changes in streams in the upper river basins of the Kyjovka and the Svratka Rivers, and over the whole Velička river basin, is presented in this article. The changes were studied using sets of old topographic maps over five periods. A numerical analysis of the changes in the main stream length and the main stream sinuosity was carried out for all three rivers. The greatest changes were found in the Velička river basin.

Shrnutí

Dlouhodobý vývoj využití krajiny a změny na vodních tocích v povodích Kyjovky, Svratky a Veličky (Česká republika)

Autoři se v tomto článku zabývají analýzami a hodnocením změn využití krajiny a změn na vodních tocích v horních povodích Kyjovky a Svratky a v celém povodí Veličky. Změny byly studovány na základě sad starých topografických map z pěti časových období. U hlavních toků Kyjovky, Svratky a Veličky byly vyhodnoceny hydrografické změny a byla provedena numerická analýza změn délky hlavního toku a změn křivolakosti hlavního toku. Největší změny byly zjištěny v povodí Veličky.

Key words: *land use, river basin, river network, old maps, Kyjovka River, Svratka River, Velička River, hydrographic changes, Czech Republic*

1. Introduction

There are many different methods used to monitor long-term land use changes – such as the processing of statistical data sets, analysis of written historical documents and archival data, mapping of land use changes based on aerial and satellite photographs, or mapping based on topographic maps on a medium scale and on cadastral maps on a large scale. Medium-scale topographic maps enable the detection of the spatial distribution of land use changes from the second half of the 19^{th} century. In the Czech Republic, a remarkable achievement represents the making public maps of the first, the second and the third Austrian Military Survey (Brůna et al., 2002). The advantage of these medium scale maps is their potential to study the changes of larger territories (Haase et al., 2007; Swetnam, 2007; Skaloš et al., 2010).

The changes in land use in the Czech Republic based on topographic maps were presented on territories delimited both from administrative and environmental views (Demek et al., 2008; Havlíček, 2008; Stránská and Havlíček, 2008; Demek et al., 2009; Havlíček et al., 2009; Mackovčin et al., 2009; Skokanová et al., 2009).

Individual land use processes, driving forces of the changes and an intensity of these changes are very often part of long-term land use development evaluation (Jeleček, 1995; Petek, 2002; Bender et al., 2005; Käyhkö and Skånes, 2006; Swetnam, 2007; Bičík et al., 2008; Bičík and Jeleček, 2009; Skokanová, 2009).

Land use changes are also often clearly detectable in the hydrography of river networks as well as in hydromorphology and/or hydrology of particular streams (e.g. Trimble, 2003; Allan, 2004; Gregory, 2006; Langhammer and Vilímek, 2008).

The study of the present state and changes on the streams or river patterns should therefore be, and in fact often is, an important counterpart to the analysis of land use changes (e.g. Hooke and Redmond, 1992;

Winterbottom, 2000; Jones et al., 2003; Demek et al., 2008). The changes on streams are analysed on different levels and in different time horizons (e.g. Downward et al., 1994; Hooke and Redmont, 1989; Kilianová, 2000; Skokanová, 2005; Žikulinas, 2008). The main information source for the study of processes on water streams are, similarly to the analysis of land use changes, sets of old maps (Hooke and Redmont, 1989; Kukla, 2007). Although hydrographic river pattern data gained from various sets of old maps are not quite comparable (because of the use of different scales, different visual display and/or approach of the authors of the maps providing a different planimetric accuracy), they can provide sufficient data for the analysis of hydrographic or hydromorphologic changes on streams (e.g. Downward et al., 1994; Matoušková, 2004; Langhammer and Vajskebr, 2007). Monitoring of land use development in selected basins of streams can be found, e.g. in studies made by foreign authors such as Trimbe (2003), Langhammer and Vilímek (2008), Benini et al. (2010) and Brázdil et al. (2011). These authors deal with correlations between land use changes and a rainfall-runoff, river pattern development, flood risks, etc. Long-term land use development in the basins of streams was studied in the Czech Republic by Havlíček et al. (2009), Brázdil et al. (2011).

2. Study area

Three medium sized basins of the Morava River were selected to monitor the development of land use and of a river pattern. To be precise, in the case of the Kyjovka River and the Svratka River the upper part of their basins to the first hydrologic station was monitored, and in the case of the Velička River it was the whole stream down to the town of Strážnice. The segment studied of the Svratka River ended by the village of Borovnice, and in the case of the Kyjovka River by the town of Kyjov.

Kyjovka River

The stream springs at an altitude of 512 m near the village of Staré Hutě on the southern slope of the Vlčák hill (561 m a.s.l.) in the Chřiby Higland, and flows into

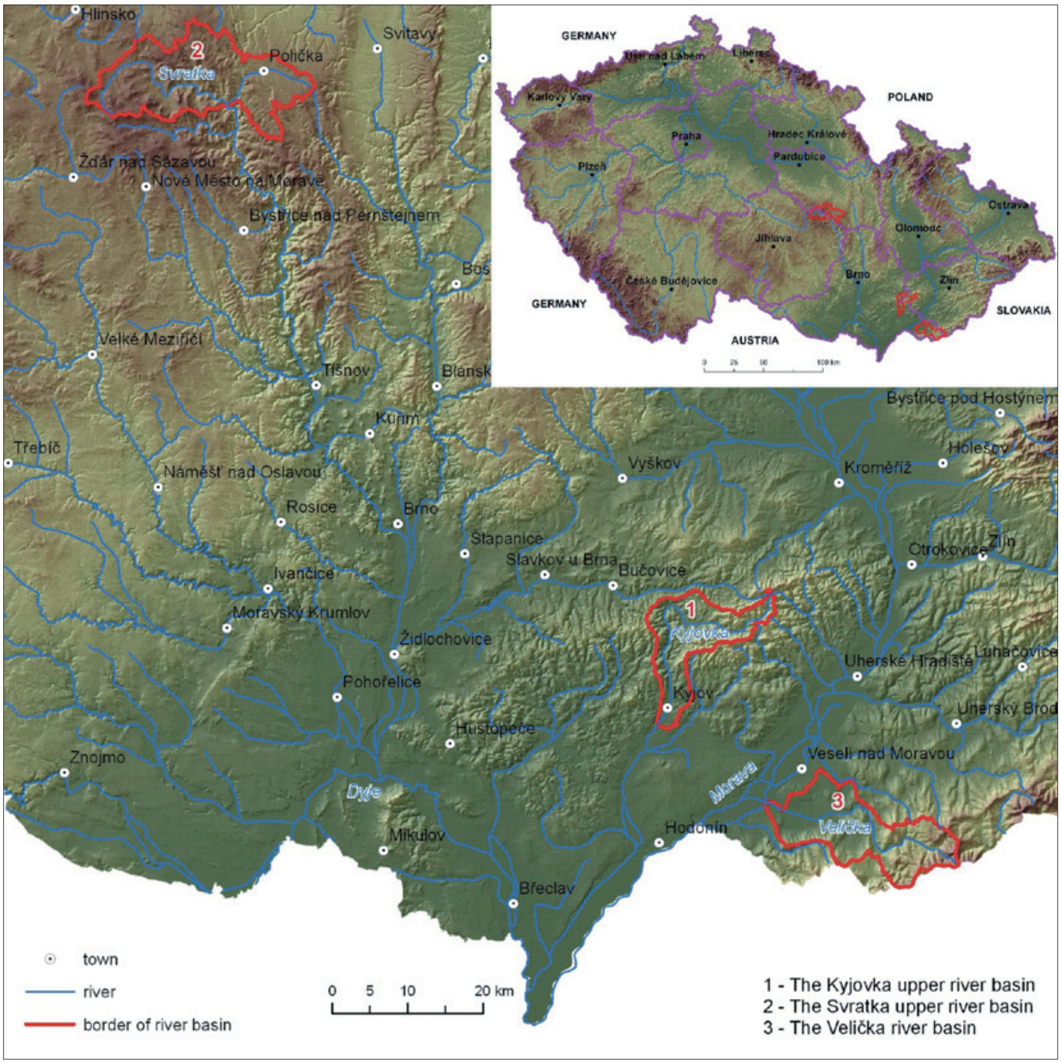

Fig. 1: Localisation of study area within the Czech Republic

the Dyje River near the town of Lanžhot at an altitude of 150 m. The total length of the stream is 86.7 km and its catchment has an area of about 665.8 km^2. The stream leaves the study area near a hydrometric profile in the town of Kyjov at an altitude of 181 m. The study area of the catchment is 124.8 km^2, the length of the segment of the stream studied is 40.7 km. The eastern part of the area belongs to the Chřiby Highland unit and the subunit Stupavská vrchovina Highland, and the northern and central parts to the unit Litenčická pahorkatina Hilly land and to the subunit Bučovická pahorkatina Hilly land. The western part lies in the unit Ždánický les Highland and the subunit Dambořická vrchovina Highland, and the southern part in the Kyjovská pahorkatina Hilly land and their subunits Mutěnická pahorkatina Hilly land and Věteřovská vrchovina Highland. A small part of southern hook belongs to the unit Dolnomoravský úval Graben and to the subunit Dyjsko-moravská pahorkatina Hilly land (Demek and Mackovčin, 2006).

Svratka River

The river rises in the Bohemian-Moravian Highland below the Žákova hora Hill (810 m a.s.l.) at an altitude of 771.9 m, and flows into the Dyje River in an area of the Nové Mlýny Dam at an altitude of 162.9 m. The total length of the stream is 168.5 km and the catchment area is 7,115.9 km^2. The river leaves the study area at the hydrometric profile at the village of Borovnice at an altitude of 515 m. The study area of the catchment is 239.3 km^2, and the length of the segment studied is 37.1 km. The largest area of the upper part of the basin belongs to the geomorphological unit of the Hornosvratecká vrchovina Highland and to its subunits of the Žďárské vrchy Highland and the Nedvědická vrchovina Highland. A very small part of the unit Železné hory Mountains and its subunit of the Sečská vrchovina Highland belongs to a study segment of the catchment to the west, and to the east is the unit Svitavská pahorkatina Hilly land and its subunits the Loučenská tabule Plateau and the Českotřebovská vrchovina Higland (Demek and Mackovčin, 2006).

Velička River

The river rises on the western slope of Velká Javořina Hill (970 m a.s.l.) at an altitude of 856 m, and flows into the Morava River near the town of Strážnice at an altitude of 169 m. The study area of the catchment is 176.9 km^2 and the study length of the Velička River is 36.0 km. The catchment belongs predominantly to the geomorphological unit of the White Carpathians and its subunits the Javořinská hornatina Mountains and the Žalostinská vrchovina Highland. Its northwestern part belongs to the unit Vizovická vrchovina Highland and its subunit of Hlucká pahorkatina Hilly land. Only a small part on the west falls into the unit Dolnomoravský úval Graben and its subunit of the Dyjsko-moravská niva Floodplain (Demek and Mackovčin, 2006).

3. Methods

3.1 Topographic maps

Land use changes have been evaluated on the basis of old and contemporary topographic maps using geographic information systems. The sources for the analysis are the following sets of maps:

- 2nd Austrian Military Survey on a scale of 1:28 800 (1836–1841) – source: Austrian State Archive / Military Archive, Vienna; Geoinformatics Laboratory, J. E. Purkyně University, Ústí nad Labem,
- 3rd Austrian Military Survey on a scale of 1:25 000 (1876) – source: Map Collection, Faculty of Science, Charles University in Prague; Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.,
- Czechoslovak military topographic maps on a scale of 1:25 000 (1953–1955) – source: Department of Military Geography and Meteorology, University of Defence; Brno, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.,
- Czechoslovak military topographic maps on a scale of 1:25 000 (1991) – source: Military Geography and Hydrometeorology Office, Dobruška; Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.,
- Czech topographic base maps on a scale of 1:10 000 (2002–2006) – source: Czech Office for Surveying, Mapping and Cadastre, Prague.

3.2 Data processing

A total of 9 basic land use categories was monitored: 1 – arable land, 2 – permanent grassland, 3 – garden and orchard, 4 – vineyard and hop-field, 5 – forest, 6 – water area, 7 – built-up area, 8 – recreational area and 0 – other area (Mackovčin, 2009; Skokanová, 2009).

Base maps of land use have been created in an ArcGIS 9.x software environment in the S-JTSK coordinate system. All the comparative maps were generated through overlaying (by use of a tool called Union) two maps of consequential periods. Other processes were used to create two synthetic base maps: (1) Number of changes in land use and (2) Stable plots. The number of changes in land use ranged from 0 to 4, due to use of five sets of maps.

As a further indicator completing the characteristics of land use changes the total intensity of changes in land use was chosen, in a similar way as used by Olah et al. (2006), Skokanová (2009) and Havlíček et al. (2009). Nine basic land use categories were grouped into five according to their intensity of landscape exploitation and were assigned coefficients: 5 – built-up area and other area (of an anthropogenic origin), 4 – arable land, 3 – orchard and vineyard, recreational area, 2 – water area and permanent grassland, 1 – forest.

By comparing land use changes between two adjacent time steps, five types of processes were distinguished: afforestation – changes of land use categories into forest; grassing over – changes of land use categories into permanent grassland; agricultural intensification – land use categories change into arable land, orchard or vineyard and hop-field; urbanization and other anthropogenic processes – changes of land use categories into built-up area, recreational area or other area and stable areas – there has been no change during the two time steps (Skokanová, 2009).

Land use development processes and their driving forces were in a similar way evaluated by other authors (Jeleček, 1995; Petek, 2002; Bender et al., 2005; Käyhkö and Skånes, 2006; Bičík et al., 2008; Bičík and Jeleček, 2009).

The total intensity of changes in land use was calculated as a grand total of the difference in intensity between adjacent mapped periods: $I = (I_{1876} - I_{1836}) + (I_{1953} - I_{1876}) + (I_{1991} = I_{1953}) + (I_{2006} - I_{1991})$. The outcome (integral numbers only) ranged from −4 to 4. Where the number 0 represents balanced landscape exploitation, i.e. plots exist in the area with stable use (plots without change in categories of use) and/or plots on which former intensification of land use is balanced by the opposite extensification. In this article, the total intensity of changes in land use are presented in maps and tables in the aggregated form as balanced land use plots ($I = 0$), plots with processes of intensification ($I > 0$) and plots with processes of extensification ($I < 0$).

The analysed streams (Figs 2 to 4) were vectorised over individual map sets with respect to their current course (i.e. with respect to the course of streams in layers A01 and/or A03 of the Digital Water Database from 2006), in order to ensure a link between the changes over the whole period, and in the case of older maps also to distinguish a particular stream from other linear elements in a floodplain. In the case of more recent map sets (from the 1990s), modified, already existing vector data were used such as DMU25 and ZABAGED. For each numerically analysed stream the total length of the stream was calculated as well as the direct distance between initial and end nodal points. There two values were used to calculate the stream sinuosity rate (Lehotský and Grešková, 2004). Changes in the length and the sinuosity of the main stream over the period from 1836 to the present are illustrated in Figs 1 to 3, and a survey of total changes for that period is presented in Tab. 7.

4. Results

4.1 Land use development

Kyjovka River. Over the period of 1836–1841 the largest share of the area in the Kyjovka upper river basin was covered by forests (43.54% of total area, see Tab. 1) and a slightly smaller share was represented by arable land (40.24% of total area). The forests were situated mainly at higher altitudes, whereas the arable land was predominantly at lower altitudes. Over the next two periods, the share of arable land increased and became larger than the share of forest. The greater share of forest returned again in the periods 1991 and 2002–2006. The biggest changes

Land use category	1836–1841	1876	1953–1955	1991	2002–2006
Arable land	40.24	46.19	49.11	39.15	35.79
Permanent grassland	11.53	6.71	0.95	3.51	6.29
Garden and orchard	0.09	0.03	0.23	1.43	1.40
Vineyard and hop-field	2.15	1.22	0.78	1.98	1.19
Forest	43.54	43.29	44.20	45.60	46.54
Water area	0.03	0.00	0.00	0.34	0.33
Built-up area	2.41	2.56	4.71	7.37	7.71
Recreational area	0.00	0.00	0.00	0.58	0.65
Other area	0.01	0.00	0.02	0.04	0.10
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Tab. 1: Land use development in the Kyjovka upper river basin 1836–2006 (proportion in %)

were connected with permanent grassland, its share reached a maximum (11.53% of total area) in the period 1836–1841 and a minimum (0.95% of total area) in 1953–1955. The process of partial permanent grassland regeneration is evident over two successive periods; the grassland re-establishment was primarily concentrated in the highlands. The share of built-up area grew by 3.2 times. The share of vineyards (there were never hop fields in study area) was the highest in the period 1836–1841 and reached its minimum in 1953–1955. The share of orchards increased in last two periods and reached a similar size as the share of vineyards. In the same period, there was a growth in share of recreational and water areas connected with the construction of the Koryčany water reservoir and a development of infrastructure required for the favourite Czech pastimes (keeping weekend houses, gardening, water sports, fishing, etc.).

Between 1836–1841 and 1876 agricultural intensification prevailed among the main processes of land use changes in the Kyjovka upper river basin, there were conversions of the area of permanent grassland, forest and vineyard into the area of arable land in this basin (4.37%, 2.08 and 1.19% of total area). The notable process was also afforestation – namely the conversions of arable land and permanent grassland into forest. Between 1876 and 1953–1955 agricultural intensification prevailed again, represented by the conversions of meadows and pastures into arable land (5.06% of total area), also afforestation occurred in some parts of the area and urbanization increased. The considerable changes in land use occurred between 1953–1955 and 1991. There can be observed an increasing relevance of grassing over and afforestation in this period. High relevance retained urbanization and other anthropogenic processes. As far as the latest period between 1991 and 2002–2006 concerns grassing over dominated, afforestation and urbanization were present only in a small extent compared to grassing over.

Svratka River. In all five periods, the biggest share of the area in the Svratka upper river basin was taken by forests (see Tab. 2). Vast expanses of the forests are concentrated mainly at higher altitudes. The second most frequent land use category, arable land, is situated mainly at lower altitudes close to built-up areas. The share of arable land reached its maximum in 1876 (40.91%), and the minimum was in 2002–2006 (25.72%). The third most frequent land use category, permanent grassland, is concentrated primarily in the surrounding areas of streams and forests, or in the hard to reach terrain at lower altitudes. The share of built-up areas increased over the whole study period by 1.9 times, mainly due to the spreading of small villages in proximity to streams. The share of other categories of land use was very low.

In the Svratka upper river basin between 1836–1841 and 1876 definitely prevailed agricultural intensification represented mainly by the conversions of permanent grassland and forest into arable land (7.14% and 2.44% of total area). At the same time the opposite processes of grassing over and afforestation occurred in some parts of the basin. Between 1876 and 1953–1955 grassing over (the conversion of arable land on 5.55% of total area) and afforestation prevailed, also urbanization increased. The process of grassing over grew stronger also among 1953–1955 and 1991 (by the conversion of arable land on 6.56% of total area) followed surprisingly by the opposite process of the conversion of permanent grassland into arable land (4.95%). There were also found significant shares of the processes of afforestation and urbanization in this

Land use category	1836–1841	1876	1953–1955	1991	2002–2006
Arable land	34.57	40.91	34.94	31.63	25.72
Permanent grassland	18.23	13.62	14.00	14.89	19.95
Garden and orchard	0.01	0.01	0.03	0.06	0.07
Vineyard and hop-field	0.00	0.00	0.00	0.01	0.00
Forest	44.24	42.95	46.61	47.69	48.56
Water area	0.18	0.08	0.09	0.16	0.24
Built-up area	2.76	2.43	4.26	5.18	5.27
Recreational area	0.00	0.00	0.05	0.33	0.15
Other area	0.00	0.00	0.02	0.05	0.04
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Tab. 2: Land use development in the Svratka upper river basin 1836–2006 (proportion in %)

period. Between 1991 and 2002–2006 definitely prevailed grassing over (by the conversion of arable land on 7.00% of total area). The processes of agricultural intensification and afforestation occurred in a substantially smaller part of the basin.

Velička River. In all five periods the biggest share of area in the Velička river basin was occupied by arable land, with the lowest rate in the period 1836–1841 and the highest one in 1953–1955 (see Tab. 3). Arable land was concentrated at lower altitudes. The second biggest rate over the period 1836–1841 belonged to permanent grassland. However, its rate gradually declined, so this category became the third most common. Areas of permanent grassland were situated mainly at higher altitudes (at the foot of the White Carpathians) and also partly at lower altitudes in the proximity of streams. The share of forests grew steadily over the whole study period, and from 1876 this land use category gained the second ranking. The largest expanse of forest was situated in the White Carpathians. Built-up area also grew steadily, the rate of which in study period increased by 2.5 times. The rate development of vineyards was mainly influenced by the decline of viniculture in southern Moravia at the beginning of the 20th century. The minimum rate was reached in 1953–1955, similarly to the land use category of orchard.

In the Velička River basin in the period between 1836–1841 and 1876 absolutely prevailed agricultural intensification, the conversion of permanent grassland into arable land occurred on 9.08% of total area. It was the most distinctive change in land use development in all three basins and across all study periods at the same time. The process of agricultural intensification also dominated between 1876 and 1953–1955, nevertheless the processes of afforestation, grassing over and urbanization were represented by significant shares at the same time. A change in the main processes occurred between 1953–1955 and 1991. The process of grassing over for the first time prevailed over agricultural intensification. The conversion of arable land into permanent grassland reached 4.05% of total area, the opposite process 2.68%. The processes of urbanization and afforestation were also significant in this period. The share of grassing over slightly increased between 1991 and 2002–2006 (up to 5.87%). followed by processes of afforestation and agricultural intensification.

4.2 Number of changes in land use and stable plots within the study area

Kyjovka River. There was at least one change in land use category for 31.71% of the total area in the Kyjovka upper river basin during the period 1836–2006. Only one change occurred in 17.88% of the total area, two changes over 10.33%, three changes over 3.02% and four changes over 0.48%. The majority of the changes were observed within built-up area (due to its gradual spread) but also in the proximity of streams (due to the disappearance of permanent grassland) and at borders of former fields (due to reconversion of permanent grassland to arable land and vice versa).

68.29% of the total area was stable plots of which vast expanses of forest represents 4,938 ha (i.e. 39.56% of the area) and arable land 3,338 ha (i.e. 26.75% of the area) situated mainly at lower altitudes. Stable plots of permanent grassland make up only 4 ha (i.e. 0.04% of the total area) which means a negligible extent in comparison to the Svratka R. and the Velička R. basins. Also, areas of vineyards went through dramatic changes, stable plots of vineyards make up only 2 ha (0.02% of the total area). Stable plots are also represented by historic districts of towns and villages (239 ha of built-up areas, i.e. 1.92% of the total area).

Land use category	1836–1841	1876	1953–1955	1991	2002–2006
Arable land	44.19	52.81	57.77	51.64	46.19
Permanent grassland	28.98	20.05	14.16	13.73	15.65
Garden and orchard	0.68	0.70	0.21	1.05	1.80
Vineyard and hop-field	2.38	1.92	0.79	2.27	2.28
Forest	21.56	22.16	23.45	25.65	28.03
Water area	0.00	0.00	0.00	0.01	0.01
Built-up area	2.19	2.34	3.57	5.53	5.58
Recreational area	0.00	0.00	0.02	0.10	0.11
Other area	0.02	0.02	0.03	0.02	0.07
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Tab. 3: Land use development in the Velička River basin 1836–2006 (proportion in %)

Svratka River. There was at least one change in land use category over 38.70 % of the total area in the Svratka upper river basin between the years 1836–2006. Only one change occurred in 18.56%, two changes over 13.72%, three changes over 5.13% and four changes over 1.30% of the total area. The majority of the changes occurred within a built-up area (due to its gradual sprawl), then to plots in the vicinity of forests and at borders of former fields (as a result of the conversion of balks, meadows, pastures and forests into arable land), but also in the category of arable land converted into permanent grassland or forest.

61.30% of the total area are stable plots, of which mainly vast expanses of forests cover 9,517 ha (i.e. 39.77% of the area) primarily at higher altitudes. Stable plots also represent 4,077 ha (i.e. 17.04%) of arable land at lower altitudes. In the category of permanent grassland, stable plots make up 783 ha (i.e. 3.27%). There is also 283 ha (i.e. 1.19%) of built-up area represented by historic districts of towns and villages among the stable plots. Without any change over the whole period 7 ha of water area also remained (i.e. 0.03%).

Velička River. In the period 1836–2006 there was at least one change in land use category on 42.60% of the total area in the Velička River basin. Only one change occurred on 26.13%, two changes on 1.42%, three changes on 4.32% and four changes on 0.70% of the total area. The majority of the changes occurred within built-up areas (due to their gradual sprawl) but also on the slopes of the White Carpathians (as a result of conversions of meadows and pastures into arable land and also due to timber felling or afforestation) and at the borders of former fields (at first due to the enlargement of arable land and afterwards due to its reconversion into permanent grassland).

57.40 % of the total area remained as stable plots during the whole period 1836–2006, which were mainly represented by vast areas of arable land (5,430 ha. i.e. 30.71% of the total area) situated primarily at lower altitudes. Stable use is also characteristic of the area covered by expanses of forest at the higher altitudes of the White Carpathians (3,391 ha. i.e. 19.18% of the total area). The area of permanent grassland made up 959 ha on all five sets of maps, which represents 5.42% of the total area and was primarily situated in the area of the White Carpathians. Historic districts of towns and villages included in the land use category of built-up area also represent stable plots (319 ha, i.e. 1.82% of the total area). The only area of vineyards present is located between the villages Louka and Blatnice pod Svatým Antonínkem (54 ha, i.e. 0.31% of the total area).

4.3 Total intensity of change in land use

Kyjovka River. In the Kyjovka upper river basin the balanced use of landscape also prevailed (75.61% of the total area, see Tab. 4 and Fig. 2). Over the whole period, intensification slightly prevailed over extensification (13.32% in contrast to 11.06% of the total area). Stable use predominated most of the geomorphological subunits, in some case interventions leading to intensification were compensated for by interventions leading to extensification. Distinctive predomination of processes of intensification occurred in the Bučovická pahorkatina Hilly land. In the Mutěnická pahorkatina Hilly land and the Věteřovská vrchovina Highland, in contrast to the Dambořická vrchovina Highland (situated at higher altitudes) intensification versus extensification was more balanced. On the other hand, prevailing extensification occurred in a spring area of the Kyjovka River in the Stupavská vrchovina Highland. The Dyjsko-moravská pahorkatina Hilly land forms only a very small part of the study area (0.78% of the total area), therefore an objective assessment of the total intensity of change in land use is not possible.

Svratka River. Unlike both the Velička R. and the Kyjovka R. basins there was a prevailing stable land use in the Svratka upper river basin (73.20%

Geomorphological subunit	Balanced	Intensification	Extensification
Dambořická vrchovina Highland	84.75	9.18	6.07
Bučovická pahorkatina Hilly land	75.14	16.87	7.99
Stupavská vrchovina Highland	76.90	5.67	17.43
Mutěnická pahorkatina Hilly land	65.61	25.02	9.37
Věteřovská vrchovina Highland	76.99	18.66	4.35
Dyjsko-moravská pahorkatina Hilly land	27.67	72.33	0.00
River basin total	*75.61*	*13.33*	*11.06*

Tab. 4: Total intensity rate of land use change in geomorphological subunits of the Kyjovka upper river basin 1836–2006 (proportion in %)

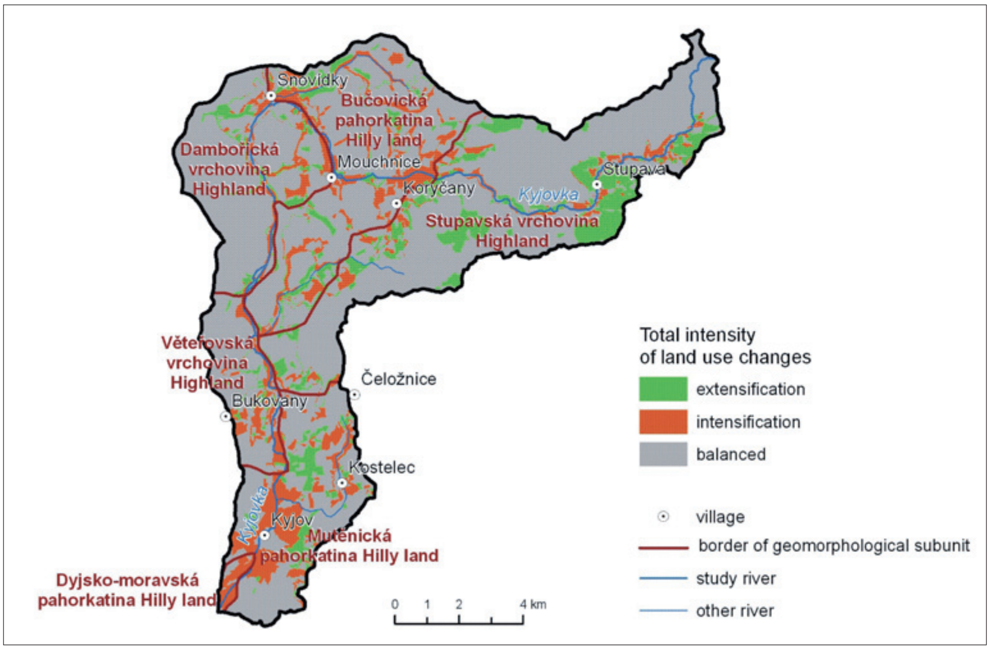

Fig. 2: Total intensity of land use change in the Kyjovka upper river basin (1836–2006)

of the total area, see Tab. 5 and Fig. 3). and over the whole period extensification prevailed over intensification (16.79% as opposed to 10.01% of the total area). Distinctive predomination of processes of extensification occurred in the Nedvědická vrchovina Highland and in the Žďárské vrchy Highland. There was obvious afforestation and part grassing over of landscape here, whereas in areas of the Loučenská tabule Plateau. the Českotřebovská vrchovina Higland and the Sečská vrchovina Highland intensification prevailed, presumably because of a higher rate of arable land in the area.

Velička River. The balanced use of landscape prevailed in the Velička River basin, founded on 65.55% of the total area (see Tab. 6 and Fig. 4). The area was characterised by stable and balanced use of land (i. e. interventions leading to intensification were compensated by opposing ones). Over the whole period, intensification slightly prevailed over extensification (18.33% as opposed to 16.13% of the total area). Intensification distinctively predominated in most of geomorphological subunits. namely in the Dyjsko-moravská niva Floodplain at the lowest altitude. Only in the case of the Javořinská hornatina Mountains did extensification prevail.

4.4 Changes on streams

Kyjovka River. The analysed stream (Fig. 2) begins at its spring and ends at the confluence with the Sobůlský potok Brook. The greater part of the Kyjovka River floodplain is narrow and only at sites of former water reservoirs and towards the end of the floodplain does it get broader. Considerable parts of the stream were mainly influenced by the construction of a number of relatively large water reservoirs before 1836 situated in broader segments of its floodplain (resulting in straightening and branching of the stream especially at sites of former water reservoirs). Subsequently the processes of straightening are not too distinctive and both a reduction of the stream length and changes in the main stream sinuosity are negligible (see Fig. 5 and Tab. 7).

Geomorphological subunit	Balanced	Intensification	Extensification
Loučenská tabule Plateau	73.62	14.73	11.65
Českotřebovská vrchovina Highland	90.44	7.24	2.32
Nedvědická vrchovina Highland	57.87	14.57	27.56
Žďárské vrchy Highland	76.18	7.88	15.94
Sečská vrchovina Highland	66.93	20.54	12.53
River basin total	*73.20*	*10.01*	*16.79*

Tab. 5: Total intensity rate of land use change in geomorphological subunits of the Svratka upper river basin 1836–2006 (proportion in %)

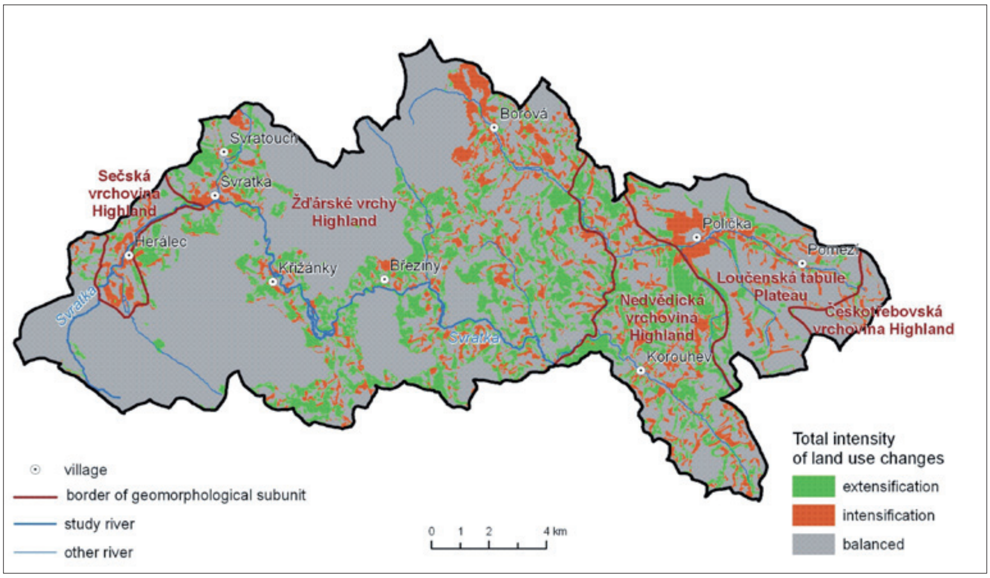

Fig. 3: Total intensity of land use change in the Svratka upper river basin (1836–2006)

Geomorphological subunit	Balanced	Intensification	Extensification
the Hlucká pahorkatina Hilly land	63.79	28.13	8.08
the Žalostinská vrchovina Highland	61.24	23.03	15.73
the Javořinská hornatina Mountains	70.07	3.97	25.96
the Dyjsko-moravská niva Floodplain	57.87	38.20	3.93
River basin total	*65.55*	*18.33*	*16.12*

Tab. 6: Total intensity rate of land use change in geomorphological subunits of the Velička River basin 1836–2006 (proportion in %)

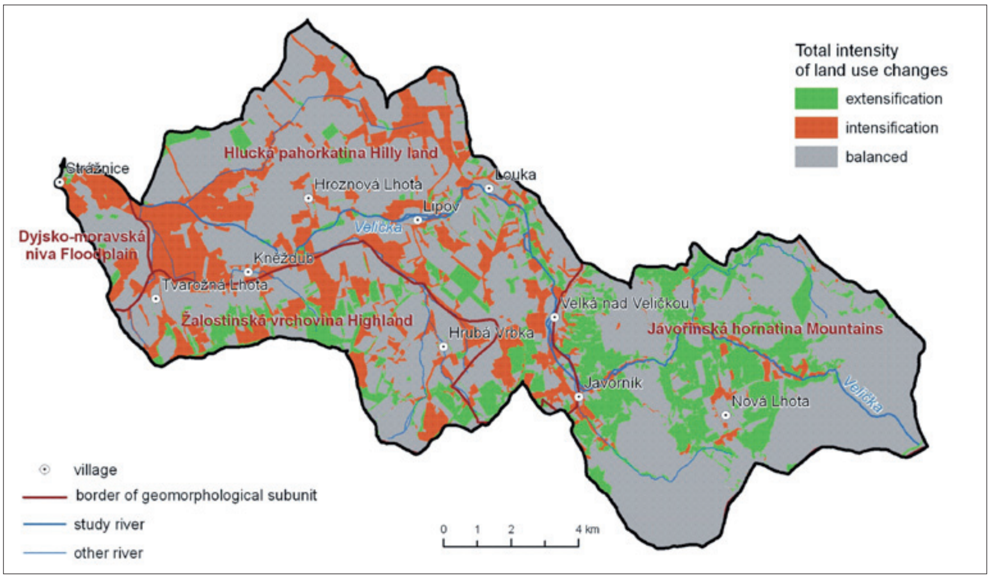

Fig. 4: Total intensity of land use change in the Velička River basin (1836–2006)

Svratka River. The analysed stream (Fig. 3) begins at its spring and ends at its confluence with the Bílý potok Brook (situated between the villages of Lačnov and Borovnice). The Svratka River floodplain is rather narrow but in some segments it becomes more or less broader. Changes on the stream due to regulation of its course and the construction of water reservoirs are negligible. Over the whole period meanders in most cases still run their course. There are slight differences in the courses of spring segments on individual sets of maps probably because of the different accuracy of each set (due to the different approach of the authors of the maps) which together with the larger scale of the latest set of maps (2002–2006) are obviously major causes of changes in main stream sinuosity (see Fig. 6 and Tab. 7).

Velička River. The analysed stream (Fig. 4) begins at its spring and ends at the confluence with the Morava River (or more precisely by its mouth with the current Baťa kanál navigation channel. i.e. former lateral branch of the Morava River). The first half of the Velička River floodplain is mostly narrow, the second half becomes slightly broader. The stream was regulated (mainly by straightening, sporadically by a change of course – replacing to an other stream bed) in broader segments of its floodplain. No water reservoirs have been constructed on the stream, and no obvious remains of older ones have been found. Stream regulations were most probably connected with the agricultural use of the landscape, flood control, eventually with road construction (at narrow parts of its floodplain). The main stream length and the main stream sinuosity were only slightly reduced (see Fig. 7 and Tab. 7).

5. Discussion

5.1 Land use development

In the study area of the basins of the Svratka River and the Kyjovka River the biggest share of the area was covered by forests during most of the period assessed, and the proportion gradually increased and varied from 43 to 48%. In the Velička River basin the biggest share of the area was represented by arable land, which varied between 44 and 58%. The third biggest rate belonged to permanent grassland, however there were different development trends in individual basins. In all three basins the area of permanent grassland gradually declined between 1876 and 1953–1955. In the case of the Svratka River the decrease was relatively moderate, and the rate gradually returned to its original value of the period 1836–1841. In the case of the Velička River, the rate of permanent grassland dropped to the middle of the 1950s to about a half of its value from the period 1836–1841. The most visible fall of the area of permanent grassland was noted in the Kyjovka upper river basin, from about 11% (1836–1841) to less than 1% (1953–1955). However, subsequent return to more extensive agriculture helped re-establish some of the meadows and pastures.

For all three study areas there was a characteristic increase in the share of built-up area. The rate of vineyards was the biggest in both the Velička and the Kyjovka river basin during 1836–1841, the decline

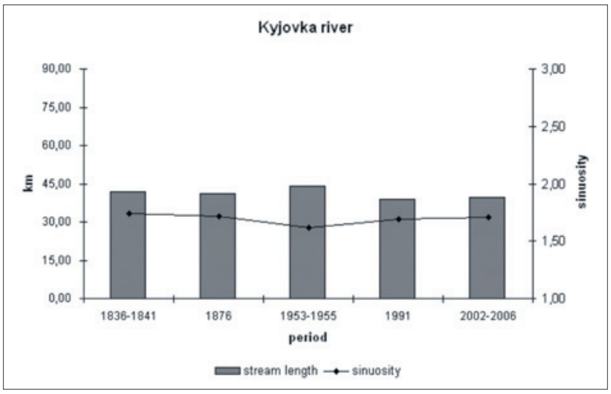

Fig. 5: Kyjovka River – changes in the length of the main stream; changes in the main stream sinuosity

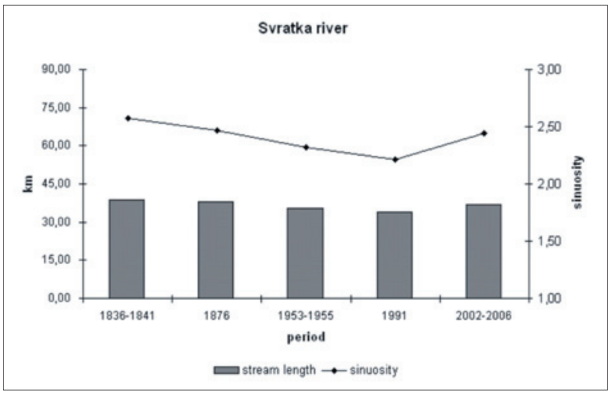

Fig. 6: Svratka River – changes in the length of the main stream; changes in the main stream sinuosity

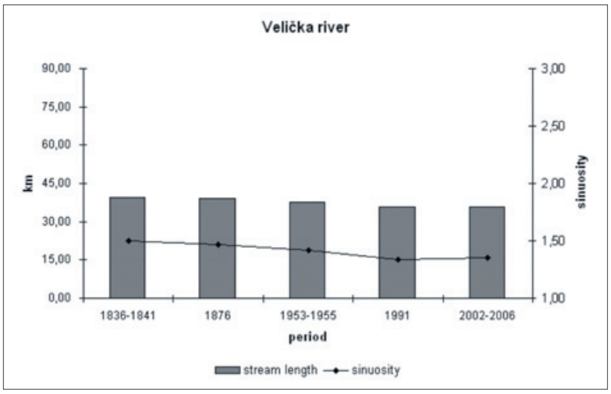

Fig. 7: Velička River – changes in the length of the main stream; changes in the main stream sinuosity

River	Main stream length change		Sinusoity change
	km	%	
Velička	−3.70	−9.33	−0.15
Kyjovka	−2.23	−5.32	−0.03
Svratka	−1.91	−4.91	−0.13

Tab. 7: Total change of the main stream length and the main stream sinuosity in analysed segments of the Velička River, the Kyjovka River and the Svratka River (1836–2006)

of viniculture in southern Moravia at the start of the 20th century was manifested by a reduction of the area of vineyards during 1953–1955. In the Velička River basin, the area of vineyards in 2002–2006 approximated original values from the mid 19th century, in comparison to the Kyjovka upper river basin, where the value remained slightly lower. The rate of orchards gradually grew in all three basins. The share of water area gradually fell at first, but later there was greater or smaller growth caused by the redevelopment or construction of new water reservoirs. The processes and changes described above correspond to findings of similar studies within the south Moravia region, e.g. of the Dolnomoravský úval Graben and the Dyjskosvratecký úval Graben (Demek et al., 2009, where the authors refer to a clear decline of the areas of permanent grassland, similarly to the lowest altitudes of the Velička River basin), in the Litava River basin (Havlíček et al., 2009) or in the district of Hodonín (Havlíček, 2008).

The basic findings about land use development in all three study basins correspond with the long-term land use development as described by the LUCC UK Prague database processed for the whole territory of the Czech Republic (Bičík et al., 2008). The consensus was found primarily in the gradual growth of the share of forest, in the significant decrease of the share of permanent grassland in the second half of the 20th century and its partial reestablishment in the present. For the whole territory of the Czech Republic and/or for smaller regional studies within its territory is characteristic the highest share of arable land at the end of the 19th century or in the middle of the 20th century and its gradual decrease till the present (Bičík et al., 2008; Demek et al., 2009; Skokanová, 2009). The consensus was also found in the gradual growth of built-up area which has been proved in all three studied basins. There was a significant decrease of the area of permanent grassland together with a continuous increase of the area of arable land till the recent period in the study area of the characteristic agricultural landscape of the Nové Dvory – Kačina (Skaloš et al., 2010). The similar pattern of land use development was observed only in the lowlands and the hilly lands of the Velička River basin.

All three basins showed some identical processes of land use development. During the comparative periods 1836 × 1876 and 1876 × 1953 the process of agricultural intensification prevailed, in contrast to the periods 1953 × 1991 and 1991 × 2006 when grassing over prevailed mainly. Agricultural intensification in the second half of the 19th century can be explained by these driving forces: the abolition of serfdom, the climax of the agricultural revolution and in case of the Velička River also by the differential rent I (Jeleček, 1995; Bičík and Jeleček, 2009). Agricultural intensification in the second half of the 20th century related to the driving forces: collectivization and transformation of private plots into vast cooperative fields (Jeleček, 1995; Bičík and Jeleček, 2009). The grassing over, which was in progress till the first half of the 20th century, was driven by the impact of the differential rent II, from the beginning of the second half of the 20th century the subsidies for the cooperative and state farms placed in the substandard production conditions became significant in this process. After the year 1990 main driving forces of grassing over became the subsidies for LFA (less favoured areas) and the support of various environmental programmes (Jeleček, 1995; Bičík and Jeleček, 2009).

The process of urbanization gradually became more significant especially in lowlands and floodplains. The same findings were presented in other papers from the Czech Republic (Bičík et al., 2008; Demek et al., 2009; Havlíček et al., 2009; Skokanová, 2009). The intensity of the process of afforestation was the same across all study periods. From an aspect of the spatial distribution was afforestation concentrated mainly within the spring areas of the study basins. Similar results were presented in the paper Bičík et al. (2008). Land use development was rather different on the upper stream of the Svratka River basin where the processes of grassing over and afforestation prevailed in most of the periods. This can be explained by predominance of highlands in this basin. The processes of grassing over and afforestation were highly significant also in other mountains and highlands of Central Europe (Petek, 2002; Bender et al., 2005; Olah et al., 2006). In the lowlands and the hilly lands of Central Europe the processes of agricultural intensification and urbanization prevailed (Haase, 2007).

5.2 Number of changes and total intensity of change in land use and stable plots within studied areas

The greatest number of land use changes occurred in the Velička River basin (42.6%). This can be explained mainly by the higher rate of the area having agricultural use at lower altitudes of its basin, and also by land use change in hilly lands and in the highlands in the area of the White Carpathians and their foothills. Changes in the Svratka upper river basin embodied 38.7% of its area, the changes were represented mainly by a growing rate of forests, the disappearance and re-establishment of permanent grassland, and a gradual spread of built-up area. The lowest number of land use changes was found in the Kyjovka upper river basin (31.7%), caused by disappearance and re-establishment of permanent grassland and gradual sprawl of built-up area. Similar values over comparably long periods are described by Demek et al. (2009) in the Dyjskosvratecký úval Graben (39.0% of the changed area) and in the Dolnomoravský úval Graben (52.0% of the changed area), the area of Dolnomoravský úval Graben is described as very changed with unstable use. Havlíček et al. (2009) refer to the Litava River basin with 28.3% of area changed, which is an even lower value than the one found in the Kyjovka upper river basin.

By comparing the stable use areas in all three study basins it was found that the highest rate of forest occurs in the upper basins of the Svratka River and the Kyjovka River (about 40% of its area). The highest rate of stable use area in the arable land category is found in the Velička River basin. Similar findings (regarding the rate of stable use area and total intensity of change in land use) are also published for the mainly agricultural area of the Dolnomoravský úval Graben (Demek et al., 2009), the Litava River basin (Havlíček et al., 2009) and the Hodonín district (Havlíček, 2008). The stable area of permanent grassland at least partly remained in the Svratka upper river basin (3.3% of the area) and in the Velička River basin (5.4% of the area), its rate in the Kyjovka upper river basin is negligible (less than 0.1% of the area). Considerable reduction in the area of permanent grassland and minimum preserved area in the Kyjov region is described by Havlíček (2008).

5.3 Changes on streams

Anthropogenically conditioned hydrographic changes are present on the absolute majority of Czech streams (Matoušková, 2004; Just et al., 2005; Kukla, 2007; Demek et al., 2008; Langhammer and Vilímek, 2008; Chrudina, 2009; Chrudina, 2010a, b; and others), mainly on their central and lower parts.

Hydrographic changes on streams made by man from the beginning of the industrial revolution in the second half of the 18th century until now were studied in detail, e.g. in the Litava R. (Chrudina, 2009) and the Jevišovka River basins (Chrudina, 2010a). On the basis of the study of 5 elementary types by man conditioned processes which can exist in streams, the following was defined (Chrudina, 2010b): (1) foundation and cancellation of water reservoirs, (2) extinction of side channels (branches), (3) straightening of stream, (4) change in position of the stream mouth and (5) changes of headwaters. The above mentioned processes are also present in different proportions in the assessed segments of the Kyjovka, Svratka and Velička Rivers. The upper part of the Kyjovka River was mainly influenced by the foundation and cancellation of water reservoirs constructed at the broader parts of its floodplain. In the case of the Svratka River (on the first part of its upper segment) the same processes occurred, however in a much smaller extent. Similarly, in a small extent this also resulted in the straightening of the stream. In contrast, in case of the Velička River (where nearly the whole stream was analysed) there were no foundations or cancellations of water reservoirs, and the straightening of stream prevailed.

Langhammer and Vajskebr (2007) studied in connection with floods spatial (hydrographic) changes in the Otava River basin from the second half of the 19th century till the end of the 20th century. The biggest shortenings of the stream the authors found on the midstream and mainly downstream areas and on smaller streams in a mainly agricultural landscape. These findings correspond with the relatively small extent of shortening of all three studied streams. In the Kyjovka R. and namely in the Svratka R., their upstream areas were studied where the shortening during the whole study period was insignificant (although the small shortening of the Kyjovka River can be explained by the fact, that the stream was previously influenced by the construction of its water reservoirs). In contrast to more significant shortening of the Velička River where the whole stream was analysed including its downstream running through wide and rather intensively used floodplain.

All three analysed streams (their study length was approx. the same) vary significantly from an aspect of anthropogenically conditioned hydrographic changes. This can be explained primarily by differences in their floodplains (from other causes we can also pinpoint a connection with altitude, especially in the case of the Svratka River which is placed at the highest altitude of the streams studied and its range of anthropogenic changes was the lowest). The consequent impact of man made changes on the main stream length and sinuosity was the greatest in the case of the Velička River (see Tab. 7 and Figs. 5 to 7); the results of the analysis of the Svratka River have probably been distorted by a different range of cartographic generalisations of individual sets of maps.

The relation between the changes on streams and the land use development is complex and multi-level. It covers many aspects from spatial (hydrographic) changes of a river network through morphologic changes of stream beds, the processes of erosion and sedimentation to an impact of these changes on the biota of streams and water reservoirs, (e.g. Trimble, 2003; Allan, 2004; Gregory, 2006). Old maps provide primarily spatial (hydrographic) information about changes on river patterns and/or river streams (Downward et al., 1994; Matoušková, 2008 and others). These changes, as mentioned by Trimble (2003), Just et al. (2005) or Langhammer and Vilímek (2008), are mainly related to flood control (especially in the vicinity of built-up areas) and to changes in the agricultural use of the landscape (drainage or irrigation requirements).

With respect to the limited extent of this paper (which focuses primarily on the changes in land use) it is possible at least to mention that the hydrographic changes found on the studied streams are in most cases related to the changes in the agricultural use of their floodplains (the area of the canceled water reservoirs, mainly in the Kyjovka River basin, was usually converted into the area of arable land or permanent grassland) or to urbanization (sprawling of the built-up area connected with its flood control reflected in a local straightening of the stream). The straightening of the Velička River downstream could also relate to the drainage requirements. The impact of a development of transportation infrastructure which can also be one of the significant anthropogenic factors of the changes on river network and individual streams (Žikulinas, 2008; Blanton and Marcus, 2009), was in relation to stream hydrography observed only sporadically (the Velička River).

6. Conclusions

Land use development in all three study basins was to a relatively high degree determined by natural conditions, although the intensity of farming also had a considerable impact. In terms of the proportional representation of individual land use categories in space and time, the most important categories were forest and arable land. Forests prevailed in the Svratka River basin and in the Kyjovka River basin (in the second example except for the period of 1876 till the mid-1950s). Arable land predominated in the Velička River basin.

All three basins showed some identical processes of land use development. During the comparative periods 1836 × 1876 and 1876 × 1953 the process of agricultural intensification prevailed, in contrast to the periods 1953 × 1991 and 1991 × 2006 when grassing over mainly prevailed. The most considerable change in land use occurred in the Velička river basin (where 43% of the area was changed), slightly fewer changes occurred in the Svratka river basin (39% of the area) and similar changes in the Kyjovka river basin (32% of the area). The different physical geographic conditions of these three areas were manifested by rates of areas being exploited intensively and extensively: in the Velička and the Kyjovka river basins intensive exploitation prevailed and in the case of the Svratka river basin it was predominately extensively exploited.

Anthropogenically conditioned hydrographic changes were found on all three streams, mainly on the Kyjovka River (foundations and cancellations of more water reservoirs) and the Velička River (straightening of the stream). In the case of the Svratka River, the range of anthropogenic changes was the lowest (small changes in the course of the stream and foundations of water reservoirs). The consequent impact of these changes on the main stream length and sinuosity was the most significant in the case of the Velička River. This can be explained by the fact that the whole stream was analysed, including its downstream part through wide and rather intensively used floodplain (in contrast to the Kyjovka and the Svratka Rivers that were only upstream analysed).

Hydrographic changes on all studied streams can be in most cases related to changes of the agricultural use in their floodplains or to urbanization, sporadically also to the development of the transportation infrastructure in their floodplains.

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Authors' addresses:

Mgr. Marek HAVLÍČEK, e-mail: *marek.havlicek@vukoz.cz*
Mgr. Zdeněk CHRUDINA, e-mail: *zdenek.chrudina@vukoz.cz*
Ing. Josef SVOBODA, e-mail: *josef.svoboda@vukoz.cz*
The Silva Tarouca Research Institute for Landscape and Ornamental Gardening, v. v. i.
Department of Landscape Ecology and Department of GIS Applications
Lidická 25/27, 602 00 Brno, Czech Republic

Bc. Barbora KREJČÍKOVÁ, e-mail: *184528@mail.muni.cz*
Masaryk University, Faculty of Science, Department of Geography
Kotlářská 2, 611 37 Brno, Czech Republic

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SELECTED CHANGES OF ARABLE LAND IN SLOVAKIA AND BULGARIA DURING THE PERIOD 1990–2006

Monika KOPECKÁ, Rumiana VATSEVA, Ján FERANEC, Ján OŤAHEĽ, Anton STOIMENOV, Jozef NOVÁČEK, Ventzeslav DIMITROV

Abstract

Changes in arable land use in Slovakia and Bulgaria over two time horizons (1990 to 2000 and 2000 to 2006) are characterized in this paper. Two data layers of land cover changes of the CORINE Land Cover Data Base were used as entry data. The evaluation of changes also considered statistical data about the changing structure of the land resources and sown areas of individual crops for the mentioned periods. The transition from a command economy to a market economy manifested itself in Slovakia by extensification of agriculture in submountainous areas, and by the spatial diversification of plant production as a result of transformation of the original cooperatives into smaller farms. In Bulgaria the changes were mainly represented by transformation of arable land to pastures and they were connected with the closures of agricultural collective farms.

Shrnutí

Změny ve využití zemědělské půdy na Slovensku a v Bulharsku v transformačním období (1990–2006)

Cílem příspěvku je charakterizovat změny ve využívání orné půdy na Slovensku a v Bulharsku ve dvou časových horizontech: v letech 1990 až 2000 a 2000 až 2006. Jako vstupy byly použity datové vrstvy změn krajinné pokrývky CORINE Land Cover a statistická data o měnící se struktuře půdního fondu a osevních plochách jednotlivých plodin za roky 1990–2006. Přechod od centrálně plánovaného hospodářství k tržní ekonomice se na Slovensku projevil především extenzifikací zemědělské výroby v podhorských oblastech a prostorovou diverzifikací rostlinné výroby v důsledku transformace původních družstev na menší podniky. Na území Bulharska jsme zaznamenali především přeměny orné půdy na trvalé travní porosty, což souviselo především se zánikem zemědělských podniků.

Keywords: *arable land, land use changes, CORINE Land Cover, Bulgaria, Slovakia*

1. Introduction

Understanding the patterns of land use change and its drivers is a key challenge for landscape ecology and land use science. The concept of land use transition highlights the assertion that land use change is non-linear and is associated with other societal and biophysical system changes (Lambin and Meyfroidt, 2010). The transition of agriculture in the post-communist countries has deeply affected land use in these countries where two different negative phenomena emerged: simplification of agro-diversity accompanied by the increase of monocultures (Kopecká, 2011; Varoščák, 2009), and abandonment of arable land which further manifests itself in the disappearance of the traditional landscape mosaic and eventual reduction of biodiversity (Zaušková, 2009; Sviček and Gasiorková, 2009; McDonald et al., 2000).

These changes can be studied at regional or national levels using information from real estate cadastres, the LPIS (Land Parcel Identification System) database and statistical data concerning farmland resources. Baumann et al. (2011) analysed post-socialist farmland abandonment using Landsat images from 1986 to 2008. CORINE Land Cover (CLC) data layers that reflect the status of land cover in 1990, 2000 and 2006 are also useful in assessment of the changing structure of farmland resources on an all-European level. The CLC Project was conceived as part of the all-European CORINE (Co-ordination of Information on the Environment) Programme and its aim is to ensure collection, coordination and compatibility of land cover data for individual European countries from satellite images. Updating of the original CLC90 database applying more recent satellite images (CLC2000 and

CLC2006) makes possible not only the recognition of the most recent status of landscape structure but also the assessment of short-term landscape changes (Feranec et al., 2007; Feranec et al., 2009).

According to Baumann et al. (2011), the collapse of socialism resulted in widespread farmland abandonment, but the abandonment rate varied across different regions in different countries. The aim of this paper is to characterize changes in the agricultural use of arable land in the territory of two post-communist countries, Slovakia and Bulgaria, using CLC data layers. Since the spatial concentration of arable land changes is irregular and so is their area (from the minimum mapping unit size of 5 ha to several hundred hectares), relative values were used to document these changes, particularly percentages represented by the areas of selected changes in agricultural landscape per 1 km^2. Maps of the change rate in two time horizons (1990–2000 and 2000–2006) are included. These results imply the possibility of further cartographic applications of CORINE Land Cover data and their interpretation in combination with national statistical data.

2. Methodology

Based on satellite image interpretation, the CLC project has produced a compatible land cover (LC) database of Europe at a scale 1:100 000. The main output of the project is the CLC database providing information on the physiognomic characteristics of Earth surface objects approximately in the early 1990s, 2000 and 2006.

Two data layers of LC changes, CLC 1990–2000 and CLC 2000–2006 were used as input data. Detailed information about these data layers is available at http://www.sazpsk/corine and http://nfp-bg.eionet.eu.int/ncesd/bul/clc. The following types of changes were selected from individual layers:

1. Conversion of class 211 into class 231.
2. Conversion of 211 into 242.
3. Conversion of 211 into 243.

The first type represents the change of arable land into grassland. Apart from meadows and pastures, this type of LC includes sporadically unused farmland at initial stages of natural succession. The second type represents the change of arable land into a mosaic of fields, meadows and permanent cultures (complex cultivation pattern). In general, this class includes areas formed by alternation of parcels with annual and permanent crops. In the CLC 2006 mapping of the Slovak Republic (SR), this type of change also included conversion of cultural parts with large-scale farmed arable land into parts with small-block arable land. The third type of change documents transformation of arable land into land cover principally occupied by agriculture. This is the case of changes caused by abandonment of land in mountain and sub-mountain regions followed by natural succession. The spatial distributions of these classes are represented in Figs. 3 and 8.

The methodology presented by Feranec and Nováček (2007) was applied to the assessment of the rate of the above-mentioned changes (Fig. 1).

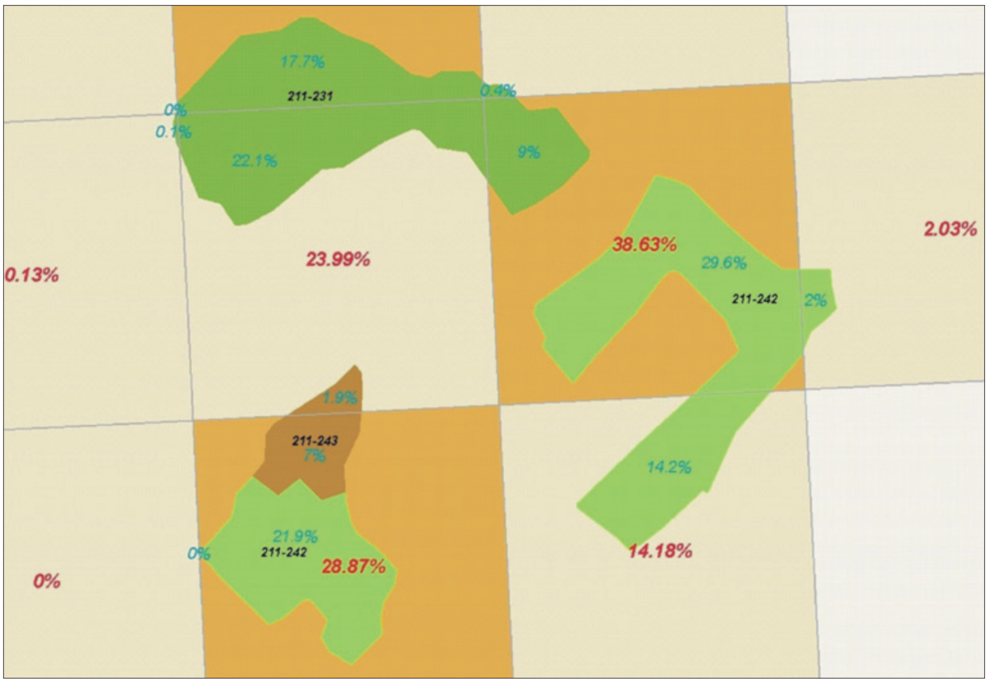

Fig. 1: Example of change rate assessment using the 1 × 1 km grid

According to percentages of changed areas per 1 km^2, the layer of CL change rate per 1 km^2 was divided into four intervals:

- less than 0.1% – no change,
- 0.1–25% – small change,
- 25.1–50% – considerable change,
- 50.1–75% – significant change,
- 75.1–100 % – complete change.

Figures 4, 5 and 9 demonstrate the rate of relevant changes.

The applied kilometre grid makes it possible to represent the frequency of changes that do not exceed 5 ha as well as at a comfortable map scale. As Feranec and Nováček (2007) report, the option for the 1 × 1 km grid was guided by its compatibility with the all-European grid developed for the database of environmental accounting (Land and Ecosystem Account Database, LEAC). This type of information can be compared to and combined with other environmental data, above all those appurtenant to GIS operations which are stored in a 1 × 1 km grid.

Recorded changes in agricultural land use were simultaneously evaluated in the context of overall changes in the structure of agricultural production. Data produced by national statistics offices concerning the changing structure of land resources and the sown areas of individual crops in the period 1990–2006, as well as available environmental and agricultural indicators from the EUROSTAT database, were also taken into account.

3. Slovakia

The total area of agricultural land in Slovakia (according to the real estate cadastre) as of 1st January 2008 amounted to 2,428,889 ha, almost half of the country's total area. This means that 0.45 ha of farmland and 0.26 ha of arable land fall to every inhabitant of Slovakia. Ownership of land in the Slovak Republic (SR) is considerably fragmented in spite of the twenty-year ongoing transformation process involved with restoration of the registry of plots. Regarding what was referred to as the "Hungarian inheritance code", 12.5 million registered plots with an average area of 0.45 ha and an average share of 12–15 co-owners are now the subject of the registry under restoration. The total 2.4 million ha of agricultural land include 52% registered on real property certificates, with the following classification: 1,054,128 ha (43.2%) owned by natural persons, 110,932 ha (4.5%) owned by legal persons and 99,415 ha (4%) owned by the State (source: MP SR 2007). This is one of the principal causes why large-scale farming still survives. Regarding an average farmed area of 119.2 ha per agricultural company, the Slovak Republic ranks second at the EU scale, following the Czech Republic.

The prevailing part of farms work on a leased land and regarding the under-developed land market, this trend holds (Tab. 1). Slow and complicated identification of ownership and fragmented ownership also contribute to conservation of the status quo. Slovakia, in an all-European context has the markedly lowest share of land farmed by owners (less than 10%). The land of unidentified owners and State-owned land is administered by the Slovak Land Resources and is available to lease. The business environment in the SR is still developing. The diminishing number of cooperatives and the increasing number of trade businesses prove this, although the greatest share in the area of farmed land corresponds to agricultural cooperatives.

4. Bulgaria

The total territory of Bulgaria is 11.1 million ha. The land for agricultural use in 2008 was 5,648,206 ha and occupied 50.9% of the country's territory. The utilised agricultural area (UAA) in 2008 was 5,100,825 ha, or 46.0% of the country's territory (Annual Agrarian Report, 2009).

The structural adjustment in Bulgarian agriculture after 1989, delays in land ownership restoration which lasted about 10 years, and the lack of consistent government agricultural policy in the first half of the 1990s resulted in different forms of land abandonment – ended or intermittent farming operations. According to the Annual Agrarian Report for 2009 of the Ministry of Agriculture and Food (MAF) of Bulgaria (http://www.mzh.government.bg/mzh/Documents/reports.aspx), the quantity of lands that are not included in the crop rotation system and are not used for agricultural production for more than two years in 2008 is 547,381 ha – which stands for 4.9% of the country's territory. The areas most affected by land abandonment are mountainous regions, which suffered from the collapse in animal breeding, as well as other disadvantaged regions, such as those with natural constraints and those with poor quality of soil. A study of the Institute of Economics at the Bulgarian Academy of Sciences „Agricultural Lands in Bulgaria: Employment and Incomes" (http://www.iki.bas.bg/en/node/651) shows that for the 10-year period since 1998, about 300 thousand hectares of agricultural lands are lost each year due to land abandonment or transfer of agricultural land for non-agricultural purposes to other sectors - industrial, recreational and protected zones, or for infrastructure and urban sprawl. Another significant problem for Bulgarian agriculture is strong fragmentation of land ownership and a large number of small farmers (Tab. 1).

The land reform was initiated in 1991 and by 2000 it was almost completed. By the end of December 2001, 98.84% of agricultural land was restored land. The land reform created 8.7 million parcels of land and established approximately 5.1 million new landowners. Almost 65 percent of the population became (co-) owners of land (Kopeva, 2002). The reform produced extreme fragmentation of land ownership in Bulgaria. The average size of agricultural plots is 0.6 ha. The size of the plots varies by region, depending on natural conditions and crop structures – from 0.3 ha in the Smolyan NUTS 3 region to 3.0 ha in the Dobrich region (Annual Agrarian Report, 2009). The fragmentation of land ownership is a significant barrier to long-term investments in agriculture, land improvements and efficient use of agricultural machinery and there is a clear need for land consolidation actions. Based on experience gained during the implementation of pilot land consolidation projects, in 2007 the Law of Agricultural Land Ownership and Use was amended to include rules for voluntary land consolidation (Rural Development Programme). Bulgaria (together with Slovakia and the Czech Republic) has the lowest share of own-farmed utilized agricultural area in Europe. Development of the land rental market, through consolidating land use, helps to overcome the problem of fragmented land ownership. The provision of land for tenant farming continues to be a priority preference for land tenure by the owners. According to the Annual Agrarian Report in 2008, a total of 154,510 tenant contracts were concluded for 327,955 hectares of land. In 2008, land tenants (co-operatives and leaseholders) numbered 7,470. The average size of land leased by one tenant is 43.9 hectares. In 2008, there is an ongoing trend of reducing the area of agricultural land use at the expense of an increase in all other areas, mainly urban and forest.

Indicator	Unit	Slovakia	Bulgaria	EU - 27
Utilized agricultural area - UAA	*1,000 ha*	1,879	2,729	156, 039
Share of utilized own-farmed area	*%*	9,1	17.0	53.6
Number of agric. holdings	*1,000*	68.6	534.6	14,478.6
Share of legal entities in number of holdings	*%*	11.9	2.7	3.2
Share of UAA farmed by legal entities	*%*	81.8	56.0	25.5
Total farm labour force	*1,000 AWU*	99	625	12,714
Family farm labour force	*% of total*	43	87	81
Agric. holders over 65 years old	*1,000*	20	222	4,722

Tab. 1: Comparison of selected agricultural indicators of Slovakia and Bulgaria (UAA – Utilized Agricultural Area, AWU – Annual Work Unit). Source: EUROSTAT (2009)

5. Results

The total area of agricultural land has been steadily decreasing in the past decades in Slovakia. As evident from Fig. 2, this decrease was also accompanied by the decrease in the area of arable land. The reduction in arable land was partially due to expanding construction but mostly to conversion of arable land into grasslands.

The soils of Slovakia, as a primarily mountainous country, contain a high share of low-productive soil types and those that are specifically disadvantaged (waterlogged, sandy or skeletal types). The size of disadvantaged areas amounts to 1,225,764 ha, or some 50% of the agricultural land resources. Analysis of CLC data layers indicated that in 1990–2000, extensification of agricultural production became obvious especially in mountain and sub- mountain regions (Fig. 3). In total, 271 changed polygons of CLC class 211 to classes 231, 242 and 243 with an overall area of 17,728 ha, were recorded. The dominant type of change was that of arable land into mosaics of fields, pastures and permanent cultures. Conversion of arable land into permanent grasslands was observed in particular in the areas of Orava, Kysuce and Slovenské Rudohorie Mts. Agricultural activities support the settlement of these less favoured areas and help to maintain the landscape diversity.

In the period of 2000–2006, with the progressive implementation of common agricultural policy into the agrarian system, spatial diversification of arable land in the area of the Danube Lowland, with high levels of diversification, was observed due to the transformation of original cooperatives into smaller firms. The recorded changes imply 407 polygons with a total area of 4,067.46 ha. Conversion of class 211 into 242 dominated in this case as well.

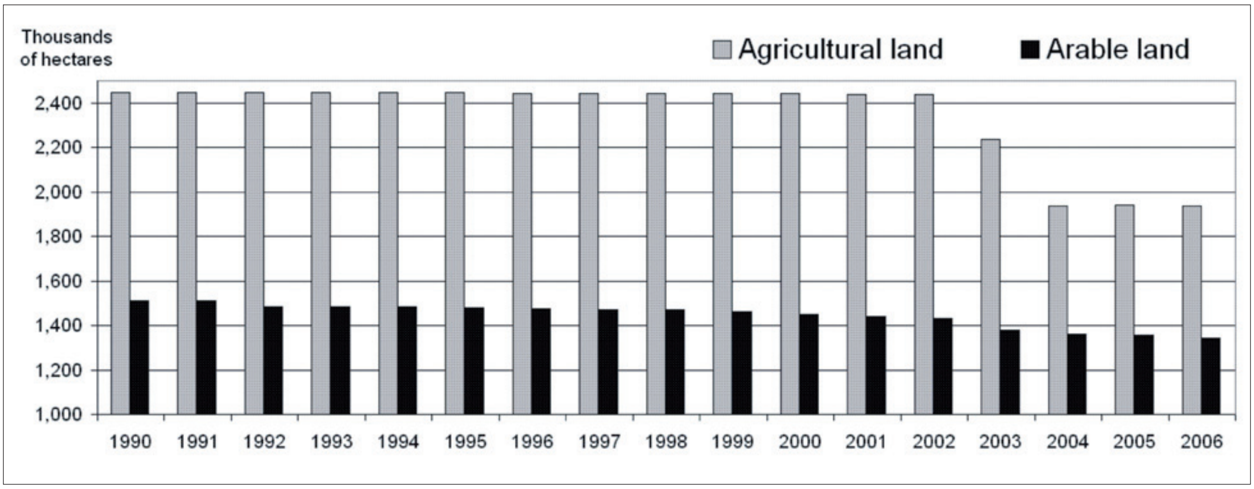

Fig. 2: Area of agricultural and arable land in Slovakia in 1990–2006

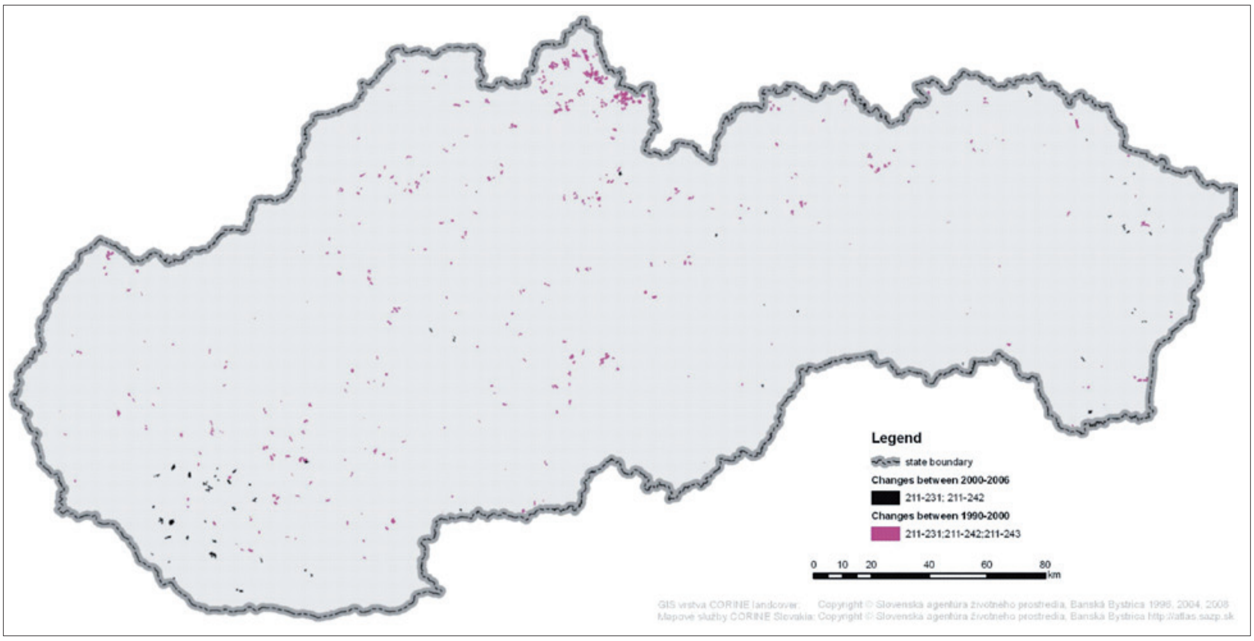

Fig. 3: Change of arable land into permanent grassland, mosaic of fields and meadows, and agricultural land with the significant share of natural vegetation in Slovakia in 1990–2006

Fig. 4 presents the spatial distribution of change rates of arable land into selected land cover classes in Slovakia in the period 1990–2000. Such graphical output provides suitable materials for combination with various elements of topographic maps and the data contained in thematic maps. Areas of small changes (0.1–25% of LC changes) occur irregularly in all sub-mountainous regions of the country. Areas of considerable changes (25.1–50%), significant changes (50.1%–75%) and complete changes (75.1–100%) were observed above all in the region of Orava.

In the period 2000–2006, all the change rate categories were recorded in the Danubian Lowland (Fig. 5). Areas of small changes occur also in Eastern Slovakia.

Graph in Fig. 6 presents a more detailed classification of change rate per sq. km in the period of 1990–2000. Obviously, more than a half of grid cells were affected by changes in question in the rate of 0.1–10%. The most extensive were the grid cells with 20.1–30% change rate.

In the past decades, the total area of agricultural land has been decreasing also in Bulgaria. The decrease in arable land was even more intensive than in Slovakia (Fig. 7). Out of 4,643,000 ha of arable land farmed at the end of socialist times, more than 1,550,000 ha were changed in 2006.

Based on the CLC analyses, arable land in the territory of Bulgaria changed above all in the years 1990 and 2000 (Fig. 8). These changes were mainly represented by the transformation of arable land to pastures, and they were connected with the closing down of agricultural collective farms.

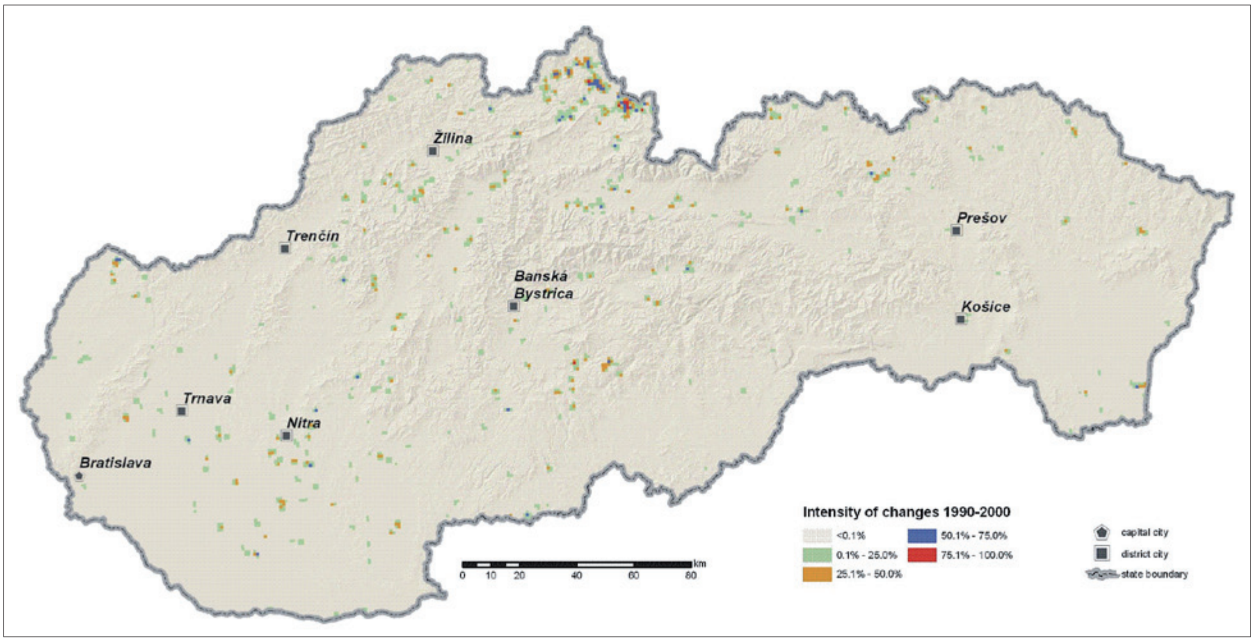

Fig. 4: Change rate of arable land in Slovakia in the period of 1990–2000

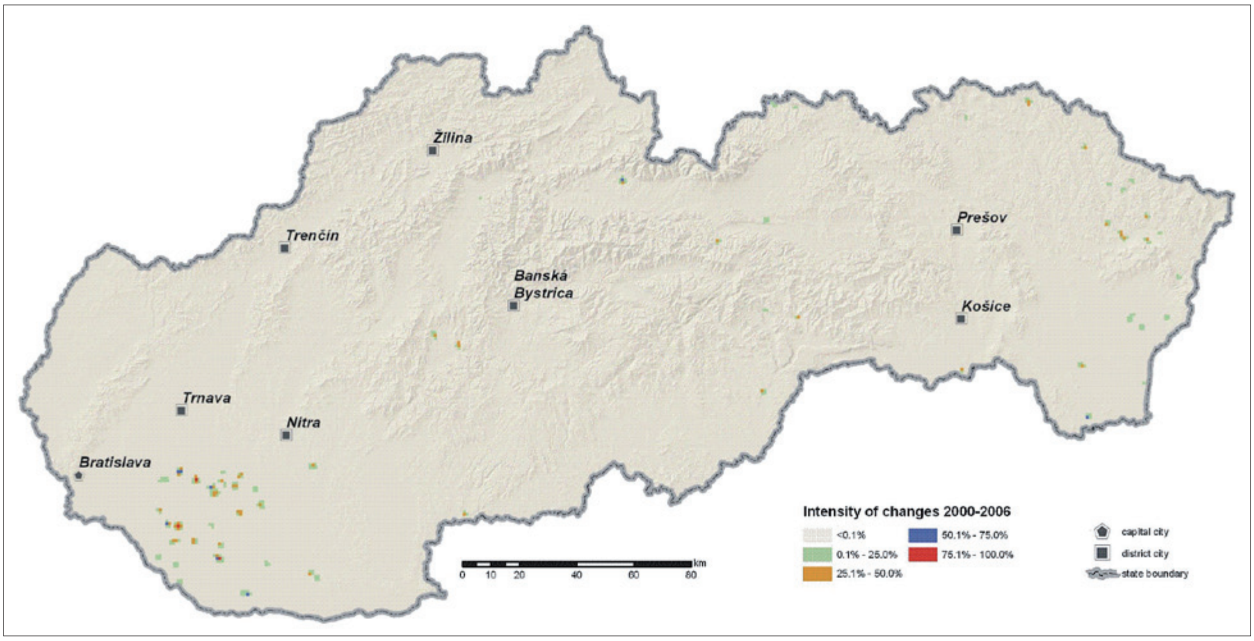

Fig. 5: Change rate of arable land in Slovakia in the period of 2000–2006

During the period 1990–2000, different change rate categories (considerable, significant and complete changes) were observed in the regions of Sofia, Plovdiv – Stara Zagora (the Upper Thracian Lowlands), as well as Veliko Tarnovo – Pleven – Montana (the Danubian Plain). Areas of small changes were registered in the Varna region (the northern Black Sea coastal zone).

As only minimum changes of arable land were observed in the time horizon of 2000–2006 in Bulgaria (only one polygon of class 211 into class 242 was observed), no separate map of the change rate was produced for that period.

The spatial distribution of CLC change intensity over the territory of Bulgaria is shown in Fig. 9, the number of grid cells and the respective area divided in 10% intervals. The maximum number of grid cells (236) are gathered in the 0.1–10.0% interval with an equivalent area of 835 km^2 (83,500 ha). The maximum changed area – 1,945 km^2 (194,500 ha) is in the range of 20.1–30%, represented by 77 grid cells.

In the graph for Bulgaria (Fig. 10), the change rate is similar to that in Slovakia in the same time horizon. In this case too, the highest number of grid cells was in the 0.1–10% rate and the most extensive

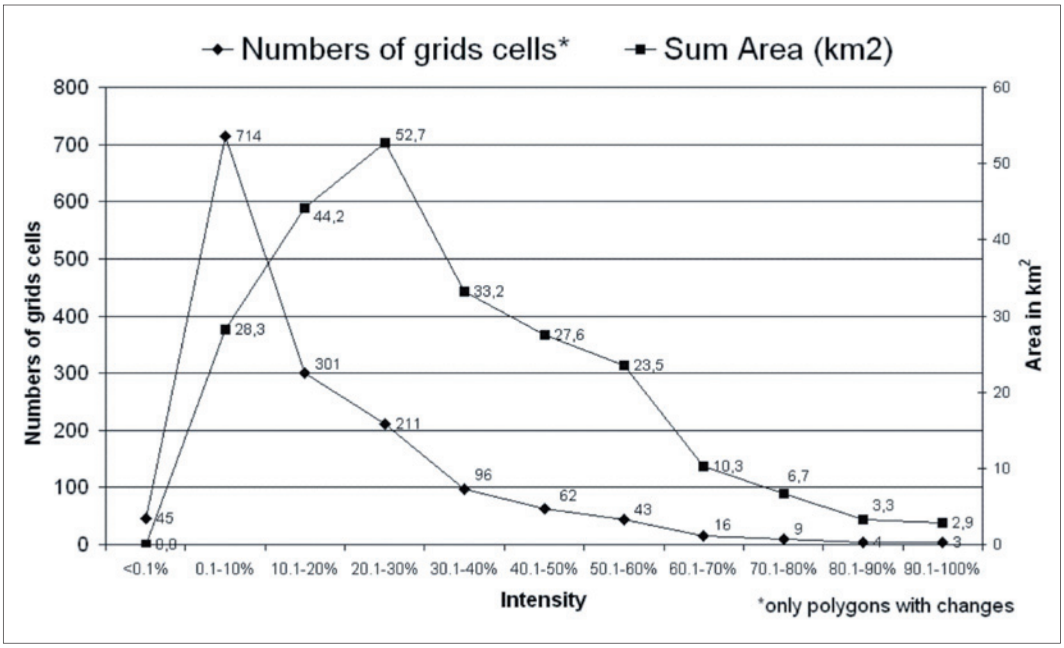

Fig. 6: Change rate of arable land in Slovakia in the period of 1990–2000

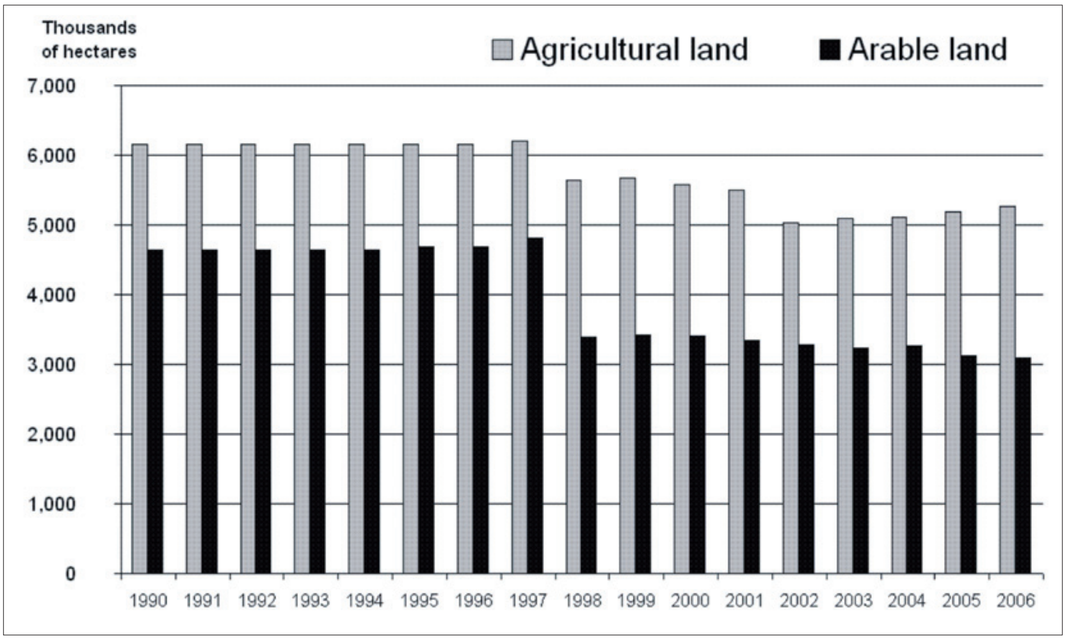

Fig. 7: Area of agricultural and arable land in Bulgaria in 1990–2006

changes were those with the 20–30% change rate. Figures 9 and 10 reflect the predominance of small area changes in Bulgaria.

Transformation processes in post-communist countries after 1989 have affected significantly the utilization of landscapes. The progressive transition from the planned economy to the market economy in both countries was accompanied by a gradual decrease in sown areas and the scale of cultivated crops. A simplification in crop diversity accompanied by the increase of monocultures is one of negative phenomena, which results in the disappearance of the traditional landscape mosaics and reduction of agro-biodiversity. In general terms, conventional, intensively farmed arable land is a poor habitat for species. For many species, however, arable land provides extensive, undisturbed foraging areas. The pattern of cultivation crop rotation and, in particular, the timing of various management activities is an important factor governing the ability of these animals to use arable land.

Changed macro-economic conditions were manifested in a marked limitation of grown vegetables, sugar beet, potatoes and legumes in Slovakia. As the numbers of

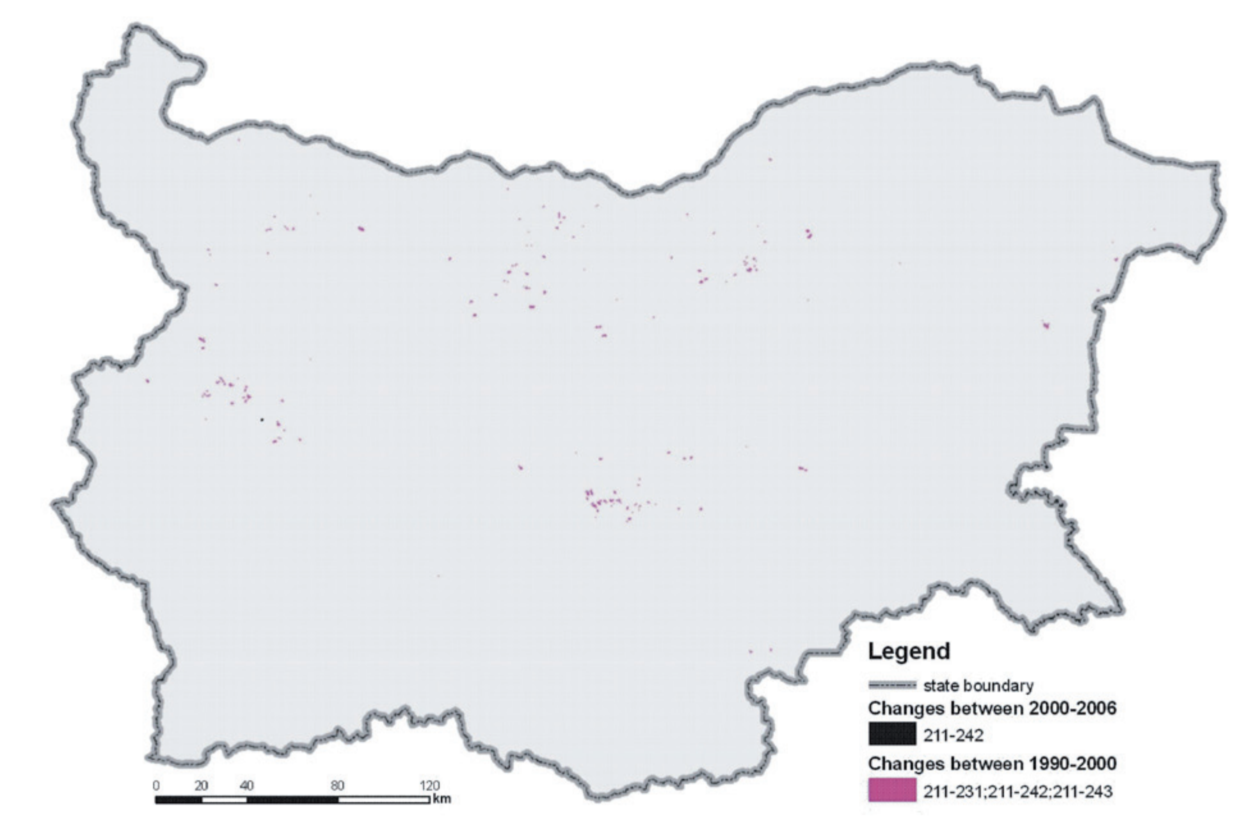

Fig. 8: Change of arable land into permanent grassland, mosaic of fields and meadows, and agricultural land with the significant share of natural vegetation in Bulgaria in 1990–2006

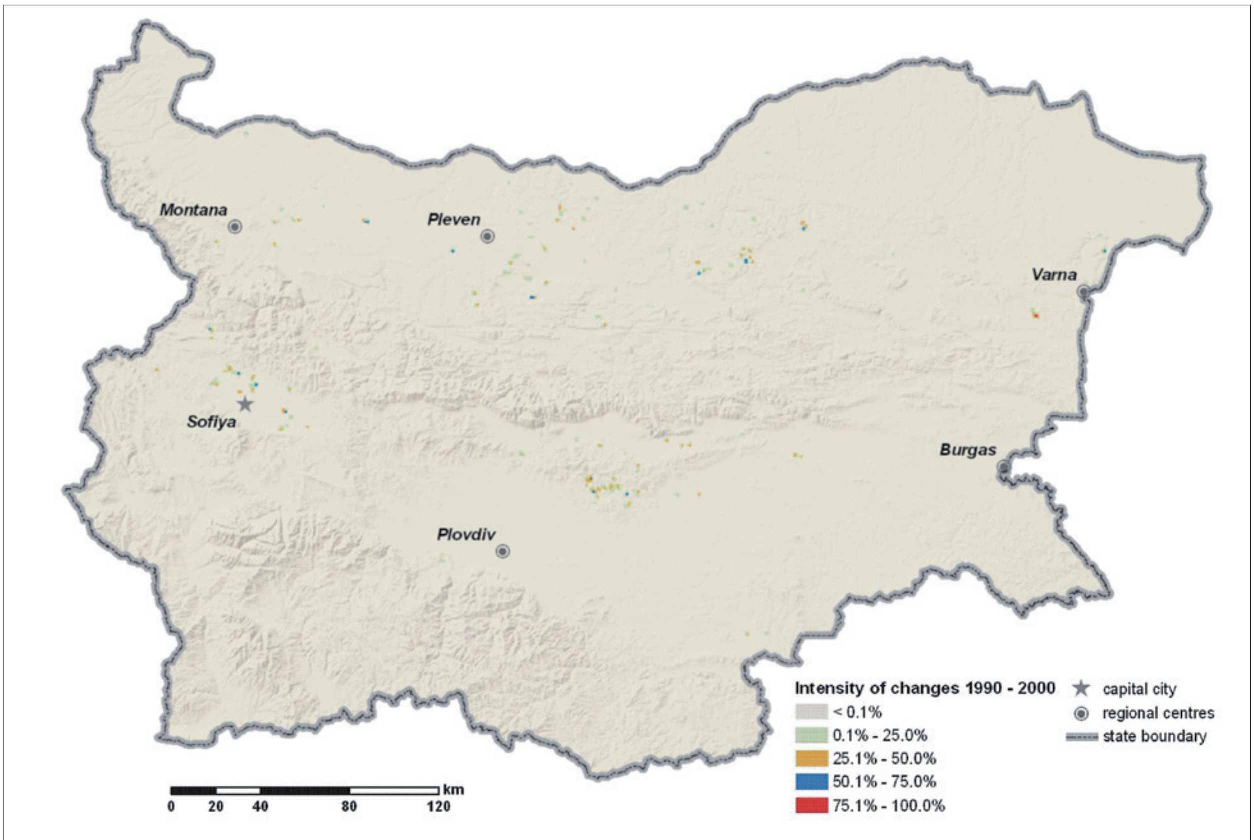

Fig. 9: Change rate of arable land in the period of 1990–2000 in Bulgaria

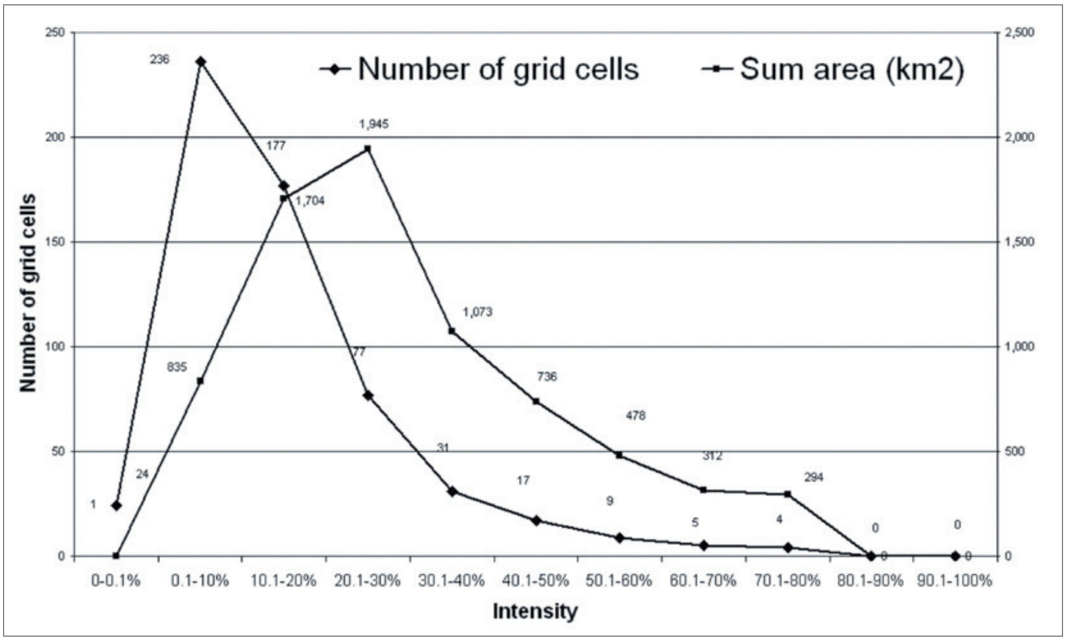

Fig. 10: Change rate of arable land in Bulgaria in the period of 1990–2000

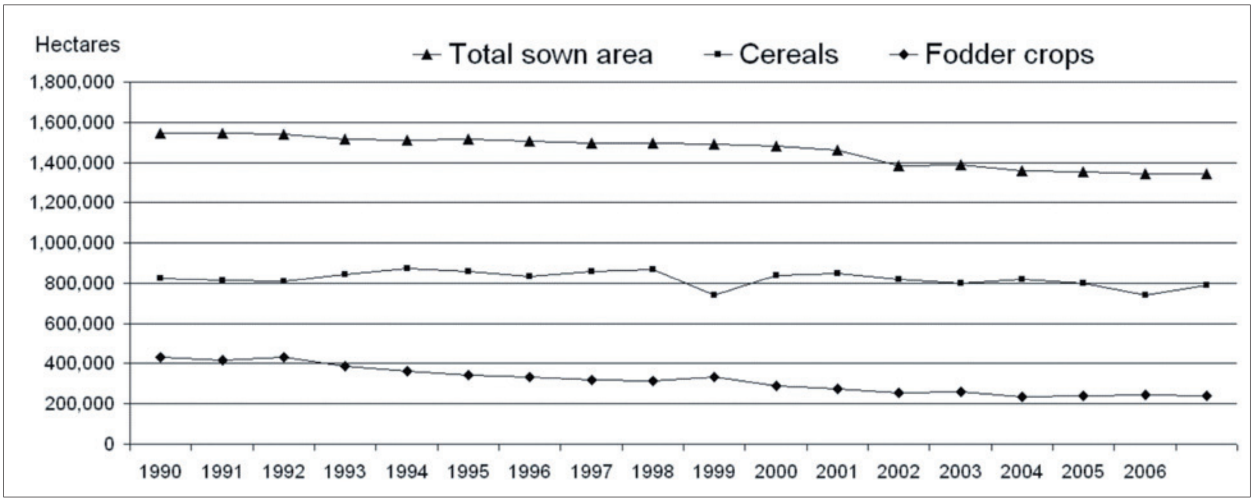

Fig. 11: Total size of sown area, cereals and fodder in Slovakia 1990–2006
Source: Statistical Office of the Slovak Republic

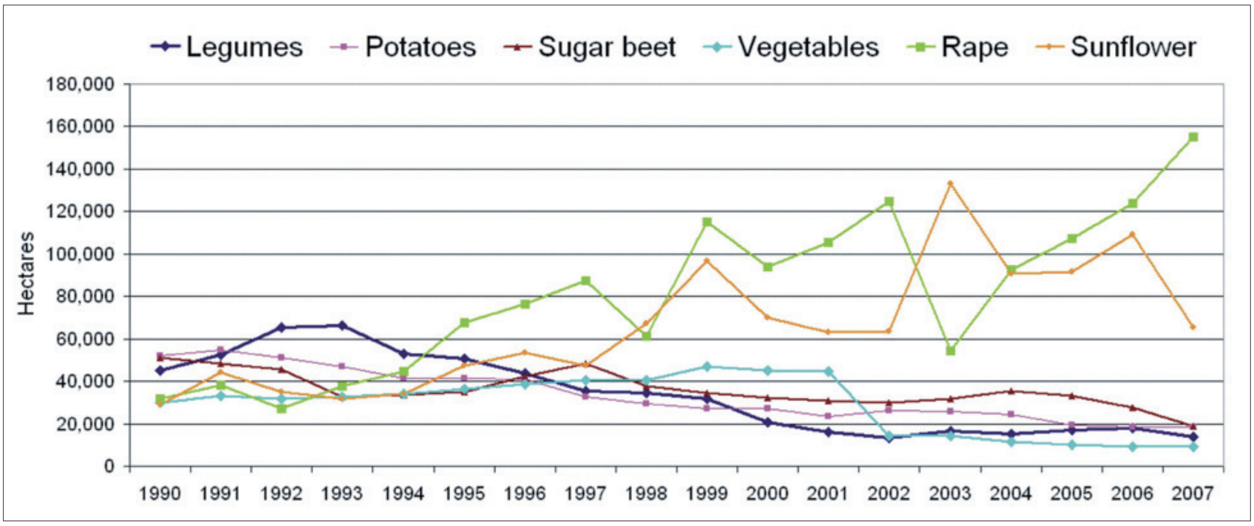

Fig. 12: Sown areas of selected crops in Slovakia. Source: Statistical Office of the Slovak Republic

farm animals dramatically dropped, the area of grown fodder decreased by 45%. In spite of the decreasing area of farmed arable land, the area of grown cereals remained relatively constant. Cereals replaced a substantial part of the originally grown crops. In turn, the area of grown oleaginous plants substantially increased (Figs. 11 and 12). For example, the area with rape seed increased from 31,762 ha in 1990 to 155,220 ha in the year 2007.

In Bulgaria, a general tendency to genetic and ecological uniformity in agro-ecosystem management is observable. The area of traditional crops, including different sorts of vegetables, leguminous plants, sugar beet and fodder plants is decreasing (Figs. 13 and 14). For example, sugar beet was planted on the area of 36,479 ha in 1990, but only on 1,356 ha in 2006. On the other hand, the area of sunflower increased from 280,203 ha in 1990 to 750,521 ha in 2006.

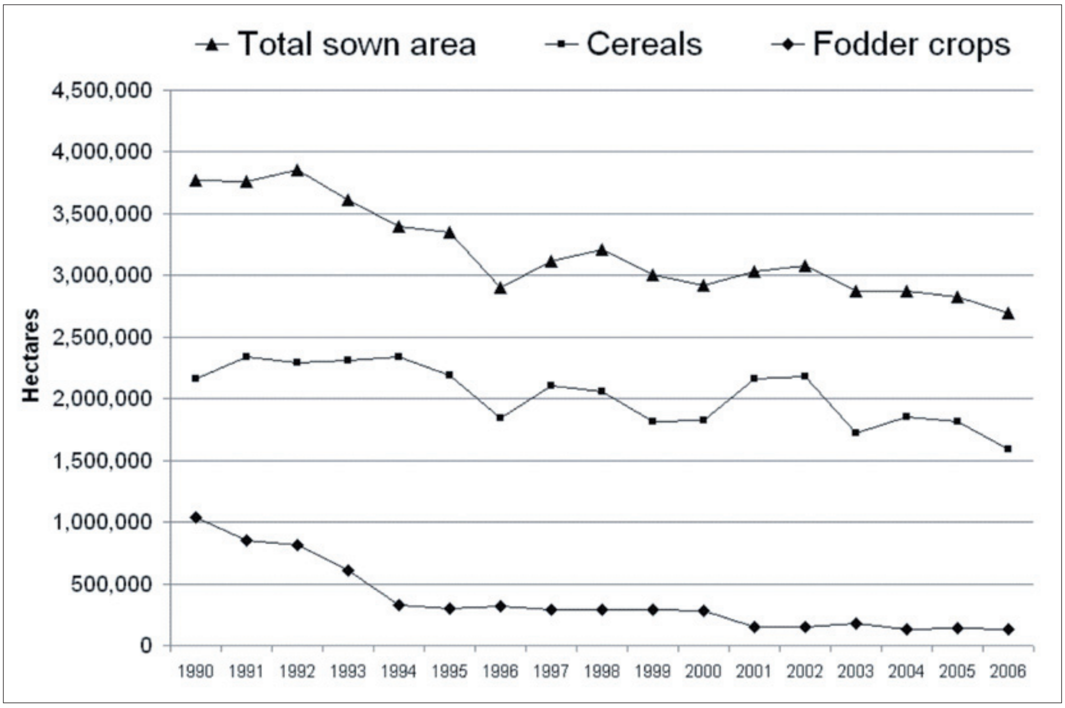

Fig. 13: Total size of sown area, cereals and fodder in Bulgaria 1990–2006. Source: National Statistical Institute

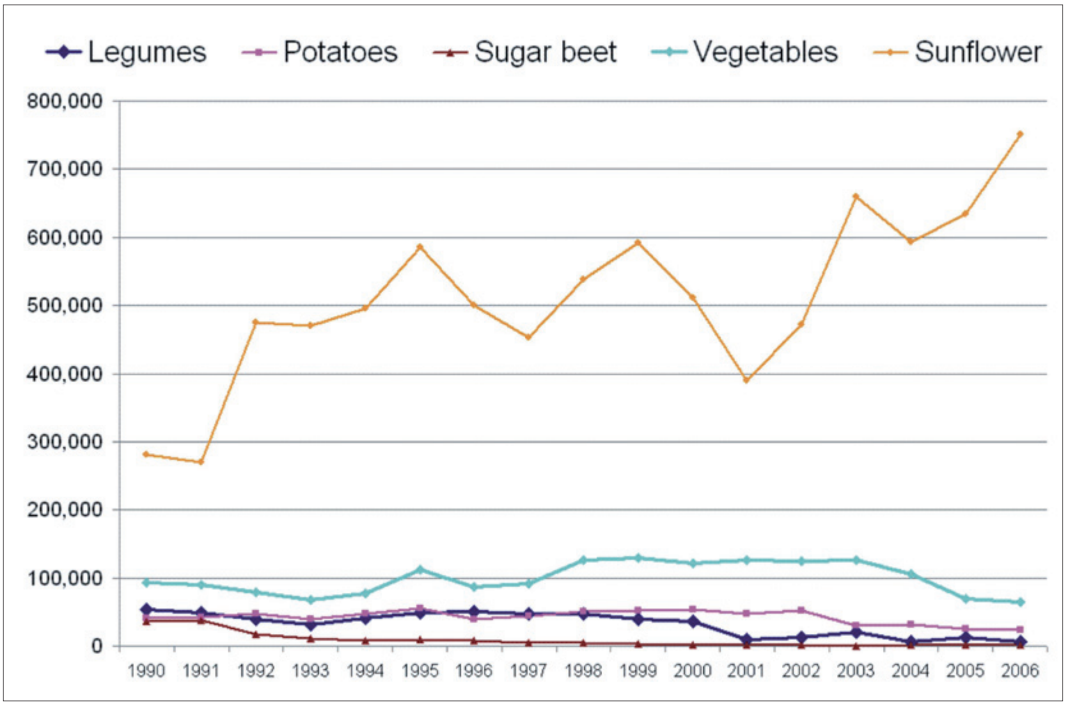

Fig. 14: Sown areas of selected crops in Bulgaria. Source: National Statistical Institute

6. Discussion and conclusion

As pointed out by Baumann et al. (2011), differences in abandonment patterns between Europe's West and East may reflect fundamentally different underlying causes that triggered abandonment and farmland changes. In Western Europe, abandonment appears to be mainly driven by gradual industrialization, market-orientation and urbanization (MacDonald et al., 2000). In contrast, abandonment in Eastern Europe was caused by the collapse of socialism and the following radical institutional and economic reforms.

CLC data make it possible to obtain more detailed information about the spatial spread of analyzed and assessed changes in the agricultural landscape, compared to statistical data related to administrative units which lack spatial identification. Accuracy of the content of CLC data oscillates around 87% (Büttner and Maucha, 2006). Spatial identification and content precision are considered important properties of the data, which represent the information source for the analysis, and assessment of changes in the agricultural landscape.

Our results document similar trends in arable land changes in Slovakia and Bulgaria between 1990 and 2006. We found more intensive farmland changes in the period 1990–2000. The period after the year 1990 was connected with the transformation of agricultural cooperatives in the former socialist countries. Processes of massive privatisation and restitution had crucial impacts on their economies because of the extraordinary drop in the numbers of agricultural workers, obsolete technologies, low buy-up prices of agricultural products, high prices of modern technologies and some other factors (Kopecká et al., 2008). Statistical data related to crop production document changes in agriculture management practices that significantly affected the utilization of agricultural landscapes.

In spite of the fact that information from CLC is not sufficiently detailed and cannot replace information from other quoted sources, this presentation and evaluation, applying a singular European methodology, facilitates international comparison of the rate of selected transformation processes and contributes to a better understanding of its drivers.

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Authors´ addresses:

RNDr. Monika KOPECKÁ, Ph.D., e-mail: *Monika.Kopecka@savba.sk*
Assoc Prof. RNDr. Ján FERANEC, DrSc., e-mail: *feranec@savba.sk*
Prof. RNDr. Ján OŤAHEĽ, CSc., e-mail: *otahel@savba.sk*
Ing. Jozef NOVÁČEK, e-mail: *jozef.novacek@sazp.sk*
Slovak Academy of Sciences, Institute of Geography
Štefánikova 49, 814 73 Bratislava, Slovak Republic

Assoc. Prof. Rumiana VATSEVA, Ph.D., e-mail: *vatseva@gmail.com*
National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences
Acad. Bonchev Street, 1113 Sofia, Bulgaria

Sen.Res.Sci. Dr. Anton STOIMENOV, e-mail: *astoimen@bas.bg*
Res. Sci.Ventzeslav DIMITROV, e-mail: *vdimitrov@stil.bas.bg*
Solar-Terrestrial Influences Laboratory, Bulgarian Academy of Sciences
Acad. Bonchev Street, 1113 Sofia, Bulgaria

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THE ROLE OF LOCAL SOCIETY IN DEVELOPING ENVIRONMENTAL CULTURE: THE CASE OF VÁC (HUNGARY)

Anna MEGYERI-RUNYÓ, Attila KERÉNYI

Abstract

The role of local society in the development of the environmental culture of cities is investigated in this paper, based on general models and on a survey that involved institutions and inhabitants of a Hungarian middle-sized town (Vác). Inner and outer factors forming the environmental culture of cities are analysed. The role of the size of cities in urban environmental protection is presented. The natural, social and environmental specifics of the town of Vác, with a population of 33,000, are analysed from the aspect of environmental protection. Environmental consciousness and the willingness of residents to take actions to improve the environment of the town are assessed using the results of a questionnaire survey.

Shrnutí

Role lokální společnosti v environmentální kultuře na příkladu maďarského města

Práce se zabývá rolí lokálního společenství v rozvoji kultury životního prostředí měst na základě obecných modelů a také na dotazníkovém šetření provedeném v institucích i mezi obyvatelstvem středně velkého maďarského města (Vác). Jsou analyzovány vnitřní i vnější faktory, které tvoří environmentální kulturu měst. Je prezentována role velikosti měst v ochraně životního prostředí ve městech. Z aspektu ochrany životního prostředí jsou analyzovány přírodní, sociální a environmentální specifika maďarského města Vác (33 tisíc obyvatel). Ekologické uvědomění a ochota obyvatel města přijmout opatření na zlepšení životního prostředí ve městě je hodnoceno na bázi dotazníkového šetření.

Keywords: *models, environmental protection, environmental consciousness, local society, urban development, Vác, Hungary*

1. Introduction

In the former socialist countries that joined the European Union, the quality of the urban environment in general was significantly poorer than in the more developed Western European countries at the time of joining the EU. Although only seven years have passed since the accession, improvement in the quality of many towns can be observed already in Hungary. In this change, a significant role was played by the approach that was represented by terms such as "green towns" or "sustainable towns", at the time of the pre-accession negotiations. Town regeneration in the professional literature discussing urban development includes the aspects that we regard as the pillars of sustainable development: economy, society and environment. According to Roberts and Sykes (2000), urban regeneration is a general and integrated approach and measures to solve urban problems and to improve economic, physical, social and environmental conditions in the long-term. Apart from financial support, the views and willingness of town leaders and inhabitants to co-operate in the solution of environmental problems, largely contribute to the development of a healthier and liveable urban environment.

Hungarian urban geographic research focuses on the urban rehabilitation of large cities (primarily Budapest) and the researchers (e.g., Kovács, 2005; Egedy et al., 2005; Mikle, 2005) mention the role of environmental consciousness of the inhabitants in urban development only in passing.

This paper focuses on analysing the environmental consciousness and willingness to co-operate of the local society regarding environmental targets, in other words the environmental culture of towns. Apart from analysing general issues, the main results of a survey conducted in a middle-sized (33,000 residents) Hungarian town (Vác) are presented.

2. Aims

In the first place, internal and external factors influencing the environmental culture of towns are analysed, on the basis of general models and the role of the size of towns on the quality of the urban environment. Then, natural environmental and social conditions and changes in the quality of the environment of Vác are presented, factors that potentially influenced the development of the environmental attitudes of the inhabitants.

Subsequently, relationships between the local government, functioning civil organizations, the dominant industrial company from an environmental point of view, and the only college in the town (Apor Vilmos Catholic College), are characterised on the basis of interviews regarding the development of the town's environmental culture.

The environmental consciousness of the inhabitants and their attitudes towards solving the environmental tasks of the town, are presented using the results of a questionnaire survey.

Finally, the controlling role of residents and green organizations in local environmental political decisions related to investments of great environmental risk, is assessed, together with the advantages of partnerships in town development.

3. Methods

A theoretical model of the internal and external factors influencing the environmental culture of towns is established and, based on this, factors dependent on and independent of town size are analysed.

Studying the literature, statistical data and the results of official investigations, the most important natural and social conditions and the environmental status of the town of Vác are analysed.

Interviews were carried out with representatives of the local government, major civil organizations, companies and the Apor Vilmos Catholic College.

The environmental consciousness of residents was studied through a questionnaire survey. Some 450 inhabitants of Vác, 18 years of age or older (including college students) were contacted in 2009 with a questionnaire containing 33 questions. Of these, 439 questionnaires were usable. The survey was carried out by a random walk method. The population of Vác over 18 years of age was included in the survey, categorized by gender, age and education. To control this, data from the census in 2001 were used. Of the 33 questions, two were open-ended and 31 were closed. At the beginning of the interview, questions representing independent variables, such as gender, age, qualification, residential area, location of flat/house and the method of sewage drainage, were asked. In the case of dependent variables, questions related to the environment were asked. The dependent and independent variables were compared using Excel software (Windows). Relative frequencies of responses were illustrated in diagrams for comparison. About one half of the survey questions directly address the aims of this paper and only those are therefore assessed.

3.1 Model of factors determining the environmental culture of a town – with Hungarian specifics

Urban environment culture is determined by numerous factors both inside and outside the town itself. These factors are changing continuously and affect the inhabitants and institutions of the given town; therefore, it is natural that the environmental culture of the town changes as well. Factors that we regard as external in this process are presented in Fig. 1.

In the broadest sense, the global environmental state of the Earth and the environmental state of the given country, together with the information on them, affect directly and indirectly the inhabitants and via them the life and functioning of towns. Spreading the information on global climate change, for example, has triggered a process that inspires institutions and inhabitants to manage and operate buildings in a more energy saving (efficient) way. For this, of course, financial help is necessary from the economic regulatory resources of the European Union, especially a careful application of subsidies to rightful efforts. The environmental policy of the European Union succeeds via the legislation, and the supportive system of member states and the country's legislation (acts and government decrees) naturally affect all of its towns. Most people become interested in extending their knowledge on the environment within the framework of institutional education. In Hungary, the urban environment-related knowledge is acquired by pupils in geography lessons taught at elementary and secondary schools, but not in detail due to the low number of lessons.

The general state of the environment and the environmental culture of the country affects the life of the town in both direct (via experience) and indirect (media, Internet) ways. The immediate surroundings of the town influence the development of environmental culture via the experience of inhabitants (with respect to attractive or to degraded nature). Civil (green) organizations (partly nationwide networks) give voice against investments endangering the environment with increasing frequency. Such an event in Hungary was the recent blocking of the construction of a military radar station near the city of Pécs ("Cultural Capital of Europe" in 2010). Activities of the Göncöl Foundation in the town of Vác are of national significance. This Foundation has one of the longest histories among civil organizations oriented to environment protection in Hungary: with the Pro Natura prize, it has a significant role not only in the field of environmental education but in its cultural, artistic, physical scientific, journal and book publication activity. The 'self-control' of large companies in environment protection affecting the environment of several towns is regarded as very important. The role of an Environmental Management and Audit Scheme (EMAS) is spreading in Hungary. Companies that operate under environmental control systems affect smaller companies and via them, for the environmental culture of towns, they are examples to be followed.

Fig. 2 represents some of the internal factors influencing urban environment culture. Those effects discussed as external factors influence town leaders, educational

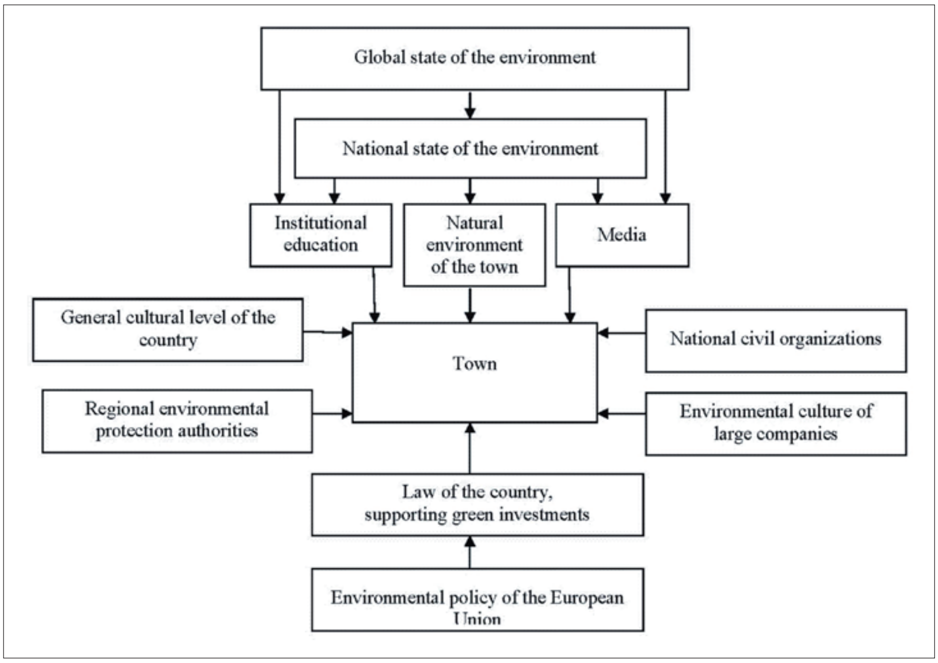

Fig. 1: Model of external factors forming the environmental culture of a town

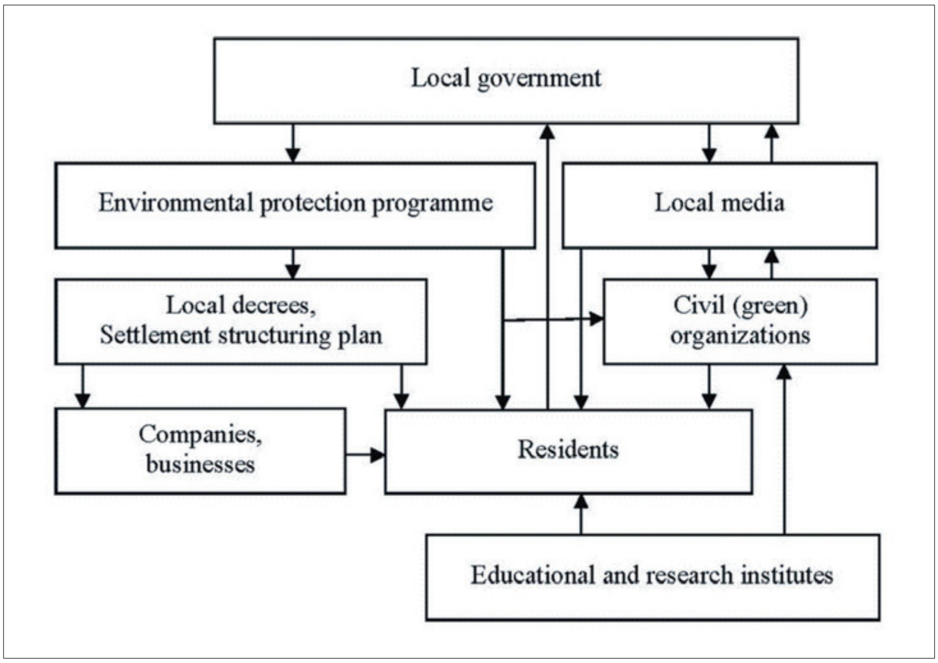

Fig. 2: Model of major factors inside the settlement influencing urban environment culture of a town

institutes, civil organizations, the larger population, companies and local media at different levels and in different ways. Operations of the local government are determined by national legislation, acts and government decrees. The tasks of local governments regarding environmental protection in Hungary are discussed in the act of 1995 on environment protection. One of the most important of these tasks is the development of an environment protection programme for the settlement, as this document, to be renewed every six years, sets middle- to long-term aims and tasks for the given town. The programme has to be harmonized with the settlement structuring plan and realization is performed by decrees of the local government. In Hungary, most settlements did not prepare their environment protection programmes despite the regulations of the act. This passivity was abandoned when the European Union negotiations started and when accession was implemented (2004), as numerous tenders were only considered if the settlement had a valid local environment protection programme. Beyond the administrative tasks, this had a significant effect on strengthening environmental attitudes.

The realization of an urban environment protection programme will be effective and successful if the local government develops co-operation and partnerships with civil organizations, inhabitants, companies and educational and research institutions in the town (Fig. 2). Particular examples for the town Vác are given later. One question is whether the size of the town influences the development and depth of environmental consciousness.

Let us examine in Tab. 1, the differences between a large city and a small town considering the environment (in Hungary small towns have populations of less than 20,000 persons, middle-sized towns have 20,000–100,000 people, and large cities have more than 100,000 inhabitants). As the development of environmental consciousness and the willingness of the population to take action in the interests of the environment play significant roles, in this paper we have to mention that public control is stronger in smaller settlements than in large cities: during a 'clean-up' action for example neighbours "speak badly" if someone's environment is untidy. The same can be observed if someone misuses containers meant for waste sorting. In Vác it is experienced that the older generation has a stronger community attitude than the younger generation.

Referring to Tab. 1, we can state that small towns are more advantageous than large towns considering the environment and Vác seems to be rather a small town than a large town.

3.2 Natural, social and environmental specifics of Vác

The town is located in Hungary, 32 km to the north of Budapest, on the left bank of the Danube River (Fig. 3). The major part of its area is at an altitude ranging from 100–120 m a.s.l., in the low and high floodplain and terraces of the Danube. The most important role in the town's life played by the Naszály Hill (652 m a.s.l.), located north of the town (for details, see later). The town is situated at the boundary of the moderately warm – moderately dry and dry climate types. Annual mean temperature is 10.0 °C in the north and 10.5–11.0 °C in the south, due to the urban heat island effect. Annual mean precipitation is 580–620 mm. Prevailing wind direction in the town is northern, northwestern.

The largest surface water course of the town is the Danube River into which two creeks flow within the town's area. The Felső-Gombás creek springs on the southern side of the Naszály Hill in the northern part of Vác; however, its bed is almost completely dry for the major part of the year due to the small catchment area. Generally it transports precipitation and cooling waters of the cement works. The other one is the Gombás creek. Small discharges of water from these creeks were polluted frequently by industrial plants operating in the area of the town in the past decade (Bíró-Kristóf, 2003).

Characteristic forests in Vác include a rosemary-leaved willow community, willow-poplar groves, oak-ash-elm groves and oak forest with lily-of-the-valley. The limestone and dolomite flora of the Naszály Hill and its high species variety richness is worth mentioning. In geographic terms, the hill belongs to the western part of the Northern Central Range (Western Cserhát) landscape, but in botanical terms it belongs to the Pannonicum floristic province due to the flora separation line extending over the Danube. Communities of Submediterranean and Pannonian character are frequent, such as open rock grasslands of dolomite slopes or the somewhat closer rock steppe and the xeromesophilous grassland community developed as a result of deforestation at the foot of the hill (Vojtkó, 2002). In a large part of the Naszály – as a result of mining – and in the built-up part of the town, no natural flora and fauna are present today. The loess wall by the entrance to the cement works, however, would require protection as it is the home of a protected bird population.

With its 33,000 inhabitants, Vác is situated near the lower limit of a middle-sized town. Its characteristic conditions resemble more the conditions of small towns. The settlement structuring plan considers Vác a small town. From an urban geography point

Condition	Large city	Vác	Small town
1. Population density	high (above 1,000 people/km^2)	(intermediate 540 people/km^2)	small (under 500 people/km^2)
2. Built-up and green areas	ratio of built-up areas is great and that of green areas is small	relatively high ratio of built-up areas, green areas are found mainly in outer parts	ratio of built-up areas is small and that of green areas is great
3. Flat supply	from luxurious flats to ghettos	good average life standard, no ghettos but poorer zones can be found	good average life standard, less number of smaller ghettos
4. Urban planning and development	difficult system with numerous parties of opposite interest	less difficult system, opposition of leaders prior and following local government elections is still present	less difficult system, smaller number of parties of opposite interest
5. Realization of the urban environment protection programme	numerous negotiations, activating inhabitants is hard	negotiations with fewer participants, mainly those parts are realized that require less investment or funds can be involved, activity of civil organizations is significant but involvement of residents is still difficult	negotiations with fewer participants, activating inhabitants is easier
6. Human relationships	estrangement, separation	good human relationships, more characteristic for older people and mothers with child benefit, relationships are made stronger by solidarity and especially by common problems people	good human relationships and mutual control of actions
7. Delinquency	frequent; destruction and aggressiveness is characteristic	rarer, less aggressive, their number was further reduced by installing cameras in the main square	rarer, less aggressive
8. Car traffic	high	especially traffic on main road 2 is high (between Budapest. and Vác)	small
9. Public transport	great capacity	urban bus traffic is significant (naturally smaller than in a large city)	small capacity
10. Energy consumption	high	small	Small
11. Industrial establishments	numerous	was higher number prior the regime change, reduced number following the political change	Few
12. Air quality	frequent exceeding of the limit values of WHO for air quality, development of smog on several occasions in the year	rarely exceeding the limit, smog is rare, greater pollution occurs along the major roads	rare exceeding of the limit, smog is rare
13. Noise pollution	significant in the major part of the town	moderate or small	moderate or small
14. Flora and fauna	species adapted to artificial environment dominate	close-to-natural flora and fauna are characteristic for the Grove, the Study Trail and the area of the Naszály	more advantageous ratio of urban and close-to-natural wildlife
15. Waste production and management	large quantity, collection is solved, recycling is variable	smaller amount, collection is solved, a complex waste management system was realized with the co-operation of 106 settlement and Vác joined the project	smaller amount, collection is solved, regional waste depositories are in operation

Tab. 1: Characteristic conditions of a large city, Vác and a small town regarding environment protection (for explanation see text)

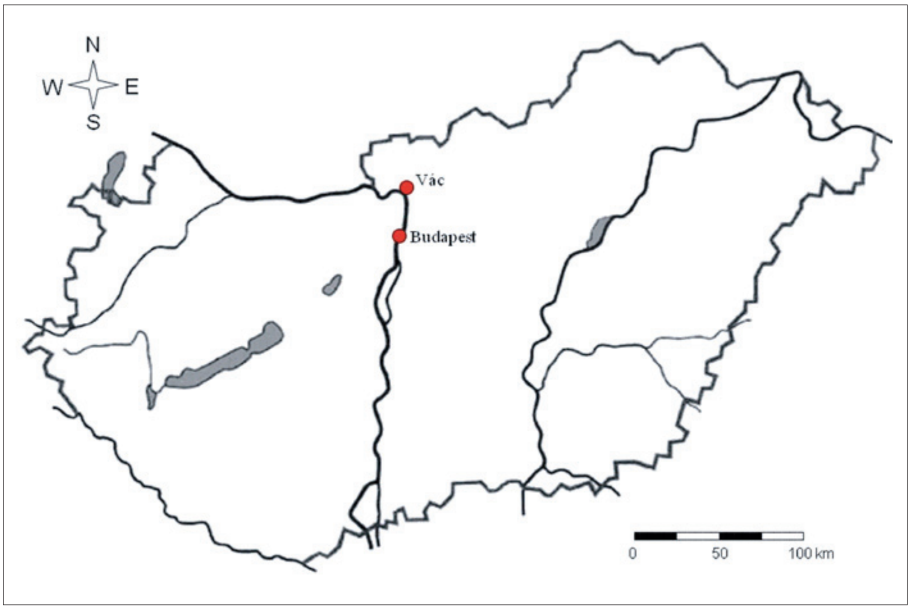

Fig. 3: Geographical location of the town Vác on the map of Hungary

of view, the town belongs to the agglomeration zone of Budapest. It has a united town structure with a historic centre surrounded by houses with gardens and panel blocks of apartments. In the outer areas, numerous weekend houses and hobby gardens can be found (Fig. 4).

Some infrastructural specifics made it stand out from the Budapest agglomeration and enhanced its position as a dominant centre of the Vác small district. The town is an administrative centre with developed industry, a health institutional network and a school network with good standards. It is an attractive destination due to its almost one thousand years of history, rich cultural life and the central role of arts. Decisive factors in attracting industrial companies to Vác include good transport conditions (the Danube River, main roads 2 and 2/A and international railway connections), closeness of Budapest and skilled labour. Based on these advantages, the town became an industrial centre (photochemistry, clothing industry, precision mechanics, electronics, chemical industry, shipyards, engine works, building material works). The Danube Cement and Lime Factory Ltd. (DCM, predecessor of the present-day Danube-Drava Cement Ltd. – DDC), operating since 1963, had a decisive role in the development of the town and its role in the town's industrial production is still significant. Raw materials are from the Triassic limestone forming the Naszály Hill, which is produced in the Sejce Limestone Quarry and appears as a significant wound in the landscape. This factory was an enormous dust releaser, especially in the 1980s, and as a consequence, Vác belonged in the group of 12 industrial towns in Hungary with the highest air pollution, often referred to as the "Dirty dozen" (Bíró-Kristóf, 2003).

Air pollution measurements have been carried out in the area of the town since 1976. Based on this, the settling dust load in the town exceeded the hygienic limit (16 g/m^2/30 days[1]) in every year until 1991, and improvement in quality appeared only after the regime change: the town average in 1990 was 29.77 g/m^2/30 days and this value was around 9–10 g/m^2/30 days after the regime change (Nagy, 2007). The severity of dust pollution increased due to the prevailing wind direction towards the town, and thus the entire town was frequently in a dust cloud. Rapid improvement at the beginning of the 1990s resulted from the reduced emissions of the new company with a more responsible environmental attitude. After 1990, dust pollution was reduced below the limit by setting a clinker burning rotary furnace into operation. In the course of the changes in the last ten years, the application of carbon dioxide reduction systems and replacement fuels intensified. Exploitation of natural resources was reduced by putting in alternative raw-materials and fuel. Thanks to the combustion gas cleaning system, emissions of pollutants are below the limit now (DDC report on sustainability, 2009).

Following the regime change numerous large factories disappeared and, as a result of the changed economic structure, several smaller enterprises were started and multinational companies appeared in the town and the service sector was developed. In this way, the

[1] KöM-EüM-FVM joint decree 14/2001. (V. 9.) on the hygienic limits of air pollution

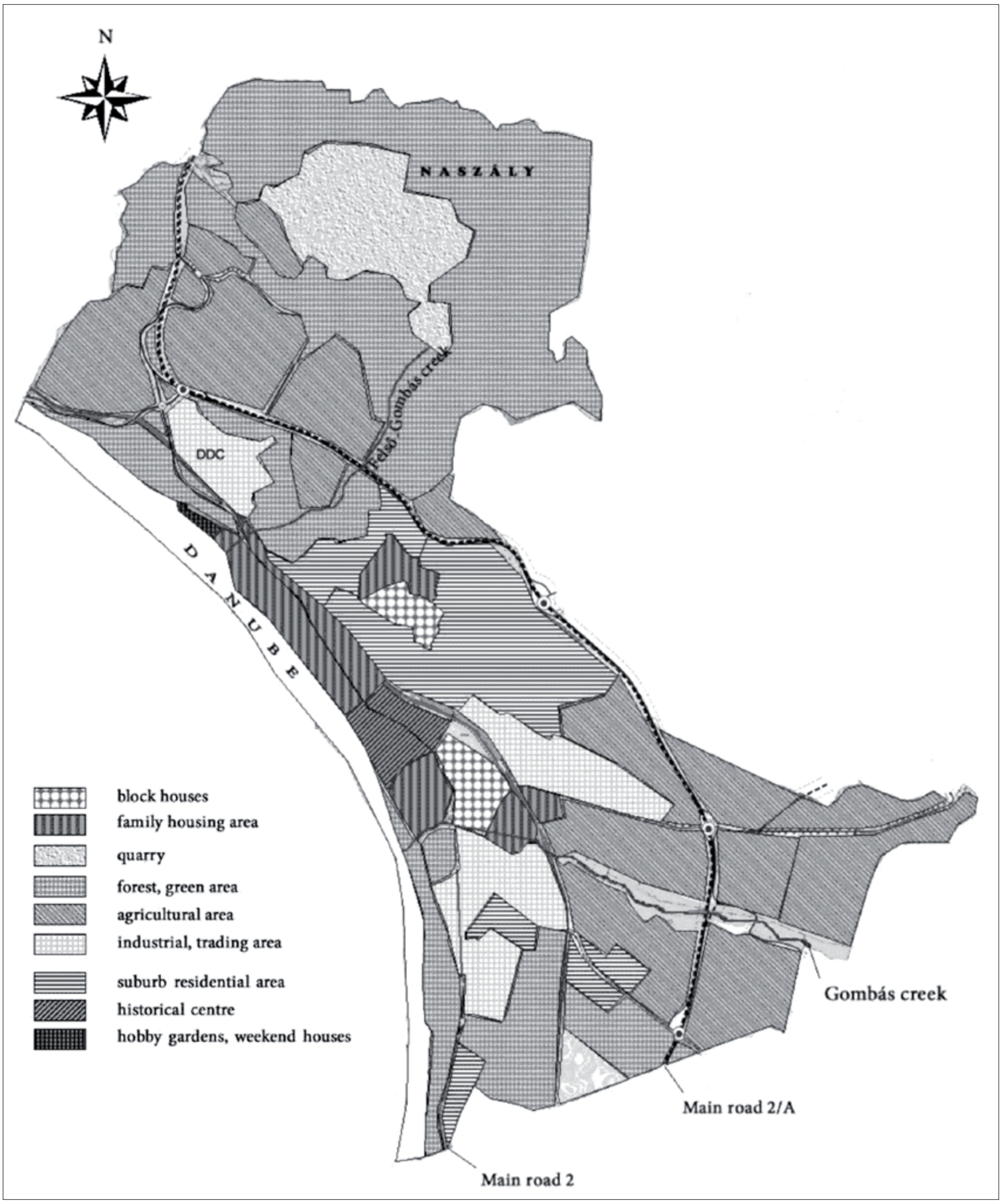

Fig. 4: Residential area types in Vác

electronic Tungsram Factory with a long tradition obtained American owners. General Electric Lighting was the new name of the company, and with significant reorganization and modernization, pollution from the factory was reduced significantly. As to chemical engineering companies, FORTE, representing the photochemical industry, was closed and the former factory area now appears in the town plans as a town rehabilitation belt. With Taurus interested in the tyre industry, Henkel founded a joint company but then it was purchased by the French company, Michelin, with major reorganization and modernization using environmentally sound technologies. Among new companies appearing in Vác, IBM is one of the major ones. The factory produces hard disc drives in close co-operation with Zollner Ltd. The textile industry with its significant production and environmental pollution, has vanished almost completely. New Hungarian factories replaced the production of the Senior Knitwear Factory of Vác, once so famous in the 1980s.

The role of food industrial branches has been reduced significantly since the change of the political system. In the preserving industry, the only company still operating is Pacific Óceán Tartósítóipari Ltd. (Pacific Ocean Conserve Industrial Ltd). Specialized in fruit processing, it became stable on the market and develops continually. The capacity of the milling industry has also declined in recent years, but production is still significant in Váci Malom Ltd. (Mill Ltd. of Vác). Naszálytej Ltd. (Naszály Milk Ltd.) is a mid-processor among milk processors, buying its source material from the surrounding region (Integrated Town Development Strategy of Vác Town, 2008–2013).

3.3 The leading role and relationship network of the local government of Vác with respect to environment protection

The environment protection programme of the town (valid until 2010) was prepared pursuant to the act of 1995 on environment protection, and it contains all issues that are required from Hungarian settlements by the act. These are the following:

a) cleanliness of residential environment;
b) drainage of precipitation water;
c) management, collection, drainage and treatment of communal sewage;
d) communal waste management;
e) protection against noise, vibration and air pollution originating from the inhabitants and public services (catering, settlement management, retail trade);
f) organization of local traffic;
g) drinking water supply;
h) energy management;
i) green area management; and
j) tasks and regulations of the settlement in order to eliminate possible special environmental risks or reduce damage to the environment.

The interview with the head of the environment protection department of the Mayor's Office focused primarily on the leading-controlling role of the local government regarding environment protection and the related network inside the town, with special regard to relationships with the inhabitants and to the development of environmental consciousness of residents. As the new environment protection programme for the next six years is under construction, questions were asked regarding the environmental prospects for the future of the local government as well.

One of the most important initiatives of the local government of the town is to prepare the Environment protection Charta for the Town of Vác and its acceptance in a wide sphere. The constitutional bases of the Charta were accepted in 2006. Companies and institutions were then approached to inform them about the idea of the Charta and to receive support from them. Following this, the Charta was signed in February 2009 and several companies have indicated a wish to join the Charta since then. Those signing the Charta agreed that realization of environmental tasks is only possible through co-operation. Therefore, the Charta aimed at co-operation and taking common responsibility of the local government, inhabitants, and social and economic organizations in parallel for the establishment of a healthy and clean urban environment. Principles of the agreement were summarized in six points in which active environment protection, partnerships, responsibility for the environment, regional co-operation, involvement of the public and sustainability are emphasized.

The main areas of co-operation are as follows:

- environment protection and nature conservation,
- built environment and regional development,
- energy,
- transport,
- healthy human environment and chemical security,
- education and attitude formation,
- sport and leisure time, and
- local and regional tasks in order to solve and handle global problems.

To make co-operation a regular item, meetings are held annually, in which works and performance of the given year are assessed, and the possibilities, fields and ways of further co-operation are defined. At the request of the Mayor, the Climate Working Group was formed in 2009 – as a civil working group having an advisory role – aimed to increase energy saving in the town and the climate consciousness of the inhabitants.

With respect to the two civil organizations important from the town's environment point of view, the local government and the environment protection office representing the local government, have strong relationships with the Foundation for the Environment Protection of Vác Town. On the other hand, the office has had connections to the Göncöl Foundation for many years. Up to 2008, issues and problems related to environment protection were discussed with the Göncöl Foundation as they were assigned by local government with telephone counselling service. The task was taken over by the local government in 2008 and a free "green number" and "green mobile" has been operated by the local government since then: numbers can be called even at weekends and problems with environment protection can be reported. In justified cases, inspection is carried out at the reported sites. ("Green numbers" or "green mobiles" are free telephone numbers that can be called from inland). The local government is naturally in connection with companies as well, for example in controlling the environmental load of companies based on reports from inhabitants. Today, companies taking social responsibility are open to the local government; thus, it has direct connections with almost all of them, for example via annual open days. Apart from these, the Charta signed in 2009 presents possibilities for further co-operation. Actual co-operation was realized in the environmental education programmes of the local government and the Duna-Dráva Cement Ltd. (DDC). The local government provides rooms for the events and publicizes them for the inhabitants and schools, as well as presenting them to the media.

The only college in the town, the Apor Vilmos Catholic College, only moved to Vác in 2004. The heads of the college regarded connections with the local government and with primary and secondary schools in the town as very important, however. Relations concerning culture, sport and environmental education are currently active. The "Pollen Project", realized by the College (with support from the European Committee), went beyond the walls of the institution: it is a project with the participation of 12 towns from 12 European countries, the aim of which is to bring science closer to the community via education. In order to achieve this, seed cities are founded that support the education of physical sciences by practical methods in elementary school, by integrating communities (families, educational institutes, local governments, etc.). During the realization of the project, teachers of the college held further trainings on teaching physical sciences by practical methods for teachers of local and nearby schools over a period of three years.

Placing environmental education on a wider foundation is planned by the college in co-operation with local civil organizations for environment and nature protection. The college also has a significant role in disseminating recent scientific knowledge. In order to do this, scientific meetings are organized frequently. One of these was the teachers' training conference entitled: "Real-life education", with a separate physical science section. At the conference entitled "Founding and endearing scientific thinking" held in November 2008, education to an environmentally conscious life received great emphasis. In the framework of teacher training, the conference entitled "Nature and man" was held in April 2011, where numerous presentations were focused on sustainability. Apart from theory, practical methods were presented at the conferences.

3.4 Effect of the dominant industrial company in the town on its environmental culture

The Duna-Dráva Cement Ltd. (DDC) prepared its "sustainability report" in 2009. The philosophy of the company is based on the principle of sustainable development and tasks in the field of social responsibility are based on this. Their motto, "in harmony with the environment", also reflects this, indicating that the company thinks in the long-term and tries to develop a harmonious relationship with its environment. Their responsibility is realized at various levels of social responsibility. For example responsibility for:

- employees and the community,
- reducing green-house gas emissions,
- energy efficiency and utilization of alternative energy sources, and
- continual high standard and reliable service for the market.

With respect to social responsibility, activities outside the company are seen in the support of environment protection, health protection, sport and local cultural events. The company management regards continual communication with both the local government and civil organizations as highly important. As a result, the company developed a wide range of relationships in recent years. The company – related to its business activity – supports the development of public areas, buildings and infrastructure contributing significantly to the development of the town. Social responsibility activities can be divided between its own initiatives and events organized in co-operation with civil organizations, and to supporting civil organizations and institutes operating in the sphere of influence of the factories.

Among this wide range of activities and support, the following can be highlighted in recent years:

- activity in establishing the Gyada study trail, opened in 2004, that was important to the company because the Sejce quarry is located on the Naszály Hill, and the development and management of the environment of the hill and the Gyada meadow are inevitable. (The study trail presents natural and cultural historic values and interests in woodlands and meadows along the Lósi River at the northern foreland of the Naszály),
- tree planting was organised along the road leading to the Gyada study trail in 2007 in co-operation with civil organizations in Vác,
- publication of the tourist map of the Naszály Hill was supported by DDC, and
- the suspension bridge on the Naszály Hill was opened on 15th November 2008 (construction was supported by DDC).

The successful co-operation of the company, the town and the civil organizations is evident in the award of the Landscape Prize of the European Council, given to the Gyada study trail in February 2009. As the company is in close relationship with its environment, DDC set a target to reduce its environmental load significantly and to prevent damage to the environment. As mentioned above, by environmentally conscious production methods and applying the best available technology, energy saving, reduction of fossil energy source usage and application of secondary basic and fuel material from waste are supported. They agreed to keep stricter limits of air pollution compared to using traditional fuels by applying alternative fuels. The quantity and quality of released material are controlled continuously by advanced technology monitoring equipment.

As mining leaves its trace in the natural environment, re-cultivation of the quarry costs around ten million forints (around 40,000 euros) every year. In co-operation with the professionals of the State Forest Survey, DDC ensures the plantation and nursing of endemic tree species in the areas excluded from cultivation. Quarry re-cultivation is always based on an ecological restoration plan.

This company operates an integrated control and quality assurance system. It applies environmentally sound technologies and takes significant social responsibility. Its target is to minimise basic material and energy consumption for cement production with the lowest possible environmental load (DDC report on sustainability).

3.5 Significance of environmental consciousness and environment protection activity of residents regarding the quality of urban environment and urban development

The following findings are based on returns from the questionnaire survey, especially those responses that refer to the knowledge of residents about the environment of the town and the willingness of the population to take action.

Almost one-third of respondents (32%) regarded air pollution as the most severe environmental problem of the town, followed by water contamination and illegal waste dumping (Fig. 5). Consideration of air pollution as a highly important environmental problem partly relates to conspicuous dust pollution from the Dunai Cement- és Mészmű (DCM) Ltd. (Danube Cement and Lime Factory Ltd.) in the past (elderly people regard the improvement subjectively and consider its extent to be less than in reality). On the other hand, car traffic has increased in Vác as well as in the entire country, and most people relate the rate of emissions to traffic. This is seen in the responses of more than half of respondents (57%) who regarded traffic as the reason for poorer air quality (Fig. 6). Despite this only around a tenth of those using their cars would be prepared to give up driving in order to improve air quality. Over one-third (34%) still regard industrial emissions (primarily the emissions produced by DDC – the successor of DCM) as the main reason for air pollution.

Respondents regard water contamination as a relatively significant problem (17% put it in the first place). This is explained by the fact that the smaller industrial factories in the town pollute the creeks running across town very infrequently, but the traces of this are visible. Talks with survey participants and information from the Mayor's Office revealed that the population of the town protested by collecting signatures against the dredging and widening of the Danube R. channel, as the increasing water transport would limit local water sport activities. In this case not ecological aspects were considered.

A question on the efficiency of sewage treatment produced an interesting result. We wanted to know the views of inhabitants on the effective operation of sewage works. Over two-thirds (67%) of respondents had no opinion and only 6% had negative opinions regarding the operation of sewage works. These data do not justify the mistrust of inhabitants considering the operation of the sewage works: improvement in the quality parameters of treated sewage water is clear compared to the 1980s. The reason for this mistrust is probably the former bad odour of the treated sewage released into the Danube River, before the reconstruction. Improvements in sewage treatment are basically the result of developments completed in 2006 in the sewage works. As a result, no pollution

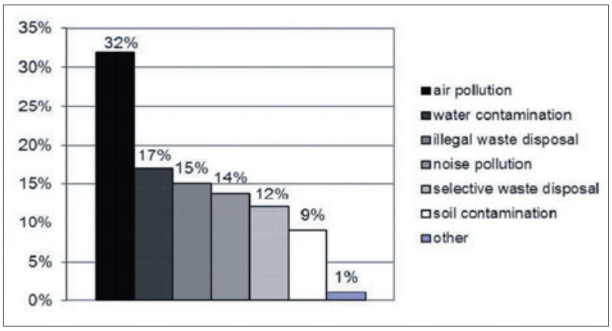

Fig. 5: Urban environment problems regarded by residents of Vác as the most severe

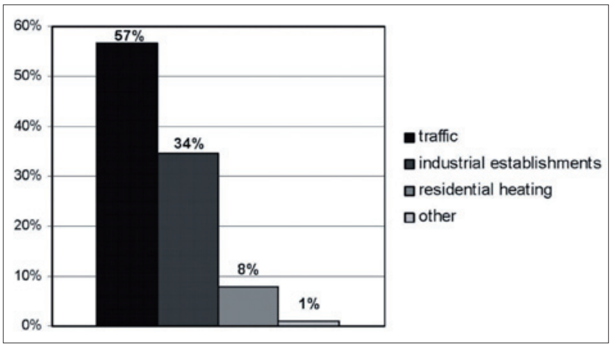

Fig. 6: Frequencies for "What causes the greatest air pollution in Vác?"

enters the Danube R. from the sewage works today – if they operate properly.

Several questions studied the knowledge and willingness of the inhabitants to take action regarding wastes. As an example: "Have you heard that a new regional waste depository is going to be established with the co-operation of the town and other settlements?". Although more than three-quarters (77%) of replies were 'no', most of the questions related to wastes received positive replies. Collection of organic and hazardous wastes and participation in selective waste collection were covered by this set of questions.

Firstly, we consider the collection of organic materials that is made possible by the construction of a regional waste depository. Almost half of those answering the questions: "Is there a need for selective waste collection? Would you take part in it?" stated that there is a demand. However, just over a quarter of them would take part in it. This corresponds to national environmental consciousness surveys: the intent is there, but acts are frequently missing (Cognative-WWF Ökobarométer, 2005). O'Connor et al. (2002) and Yarnal (2003) pointed out that acts related to environment protection are enacted most often if the individual can benefit from them and if no expenses are involved.

A similar result was obtained for the collection of hazardous wastes: 64% of respondents consider it beneficial, but only 28% would take part in it. It is positive that a high proportion of the population takes part in selective waste collection. At the national level, TNS Hungary Ltd. Carried out a representative survey in 2008 involving 1,005 people. This survey revealed that 52% of respondents collect waste selectively. Another representative survey involved 1002 people and revealed that 54% of them collect waste selectively (TNS Hungary, 2008, 2010). In Vác, 68% of respondents take part in selective waste collection which is relatively a high rate compared to the national level.

A subsequent set of questions intended to examine the relation of inhabitants to events and activities associated with environment protection. In Vác, a wide variety of programmes, actions and calls is associated with environment protection thanks to the work of local civil organizations. However, two thirds of respondents had never taken part in such events and 17% take part only rarely, 10% replied with 'yes' and 5.6% take part in all events (Fig. 7).

What can be the reasons for this response? Let us review the offered events. The local government and civil organizations organise several programmes related to environment protection and awareness for the inhabitants throughout the year. These can be grouped into the following themes: illustrious calendar days, healthy lifestyle, saving, conscious purchasing, and making the urban environment cleaner and tidier. The ratio of participants exceeds the average low value only in the case of events related to healthy lifestyle (including mass sport events). Passivity is mainly explained by everyday engagements (work, second job, travel to Budapest, etc.) and thus lack of time. These results are not encouraging because events are also included that show responsibilities of inhabitants towards the environment.

The following questions were aimed to examine opinions about the success of environmental activities of the inhabitants and the local government (Figs. 8 and 9). Some self-criticism of people can be respected as they regarded their own activity less successful than that of the local government: one quarter of respondents chose the "poor and very poor" response, and only two thirds of them regard it as „average" (Fig. 9). Thus, based on the opinion of respondents, participation of the population in events related to environment protection can be

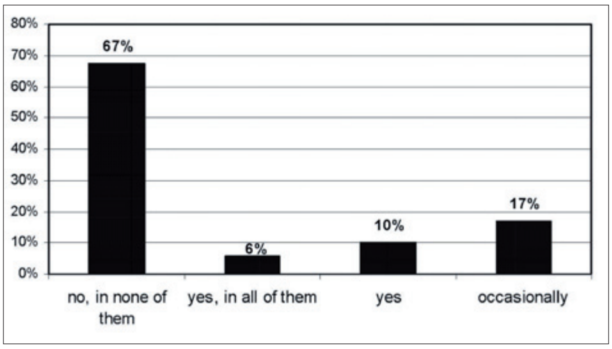

Fig. 7: Willingness of Vác residents to participate in programmes related to environment protection organised by local government and civil organizations (Do you take part in events and programmes related to environment protection?)

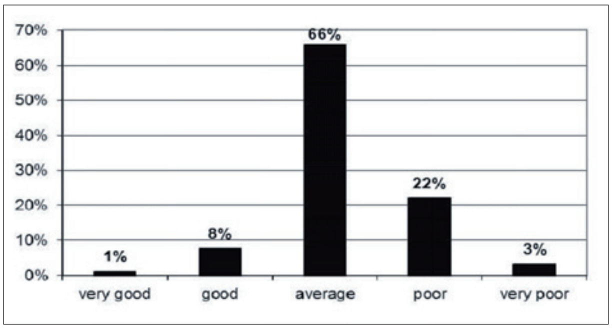

Fig. 8: Frequencies for the question "How do you regard the activity of residents considering environment protection?"

regarded as low. This is in line with responses to questions regarding participation in events related to environment protection.

Local government received better scores: only 11% of respondents regarded the local government as passive and 17% voted for the good and very good category (Fig. 9); in total, the opinion of respondents is slightly positive.

Finally, suggestions were sought for how to improve the state of the environment in the town. The relative passivity of the population is seen in the fact that 158 (36%) of 439 respondents had no suggestions. Somewhat less than one in five (16.4%) suggested the extension of selective waste disposal and the same proportion (16.8%) considered prevention of littering public areas as important. Further suggestions were very wide ranging, and only replies related to the reduction of air pollution can afford some basis (better mass transport network, extension of bicycle routes, prohibition of cars in the town centre, in total 15% of respondents) for the local government in considering investments.

4. Conclusions: partnership or opposition?

The environmental quality of a town is influenced by factors outside and inside the town. Global, regional (European Union), national and immediate natural and social environments of the given town all affect the environmental culture of the local society. In creating a liveable urban environment, however, the local participants are decisive: local government, civil (green) organizations, dominant industrial companies and inhabitants. In the town presented as an example (Vác, Hungary), environmental awareness of inhabitants is better than the national average. In absolute terms, however, those who are willing to actively participate in improving and developing the environment in the town are in the minority.

The question arises whether inhabitants and civil organizations should put emphasis on control regarding the decisions of the local government related to environmental protection.

According to national and international experience, the population has most direct connections to the civil sphere as civil ("green" in our case) organizations are formed by organising environmentally conscientious citizens. Less active inhabitants also often accept the opinion of civil organizations in environmental issues and their opposition to economic companies is also frequent, as they – according to their views – carry out or want to carry out activities harming the environment.

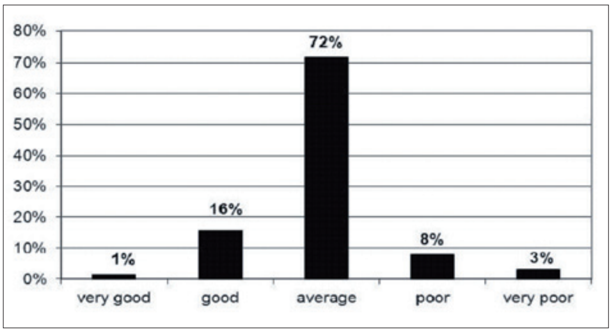

Fig. 9: Frequencies for the question "How do you regard the activity of the local government considering environment protection?"

Fig. 10 presents a revised general model of the mechanism of effects that inhabitants and civil organizations can have on local decision making. Environmental political decisions of the local government determine the development of the town environment. Inhabitants are informed about these decisions via the local television or newspapers. In the case of larger investments, it is a legal obligation to present the environmental impact assessment of the investment to the public, and public opinion has to be heard in a public hearing. During this process, inhabitants can transmit their opinions directly to the local government and to the environmental authorities also taking part in the hearings. According to experience, such remarks frequently reflect subjective individual opinions, offence or apprehension – and their effect on the final decision is very low (Fig. 10).

A stronger influence is evidenced by citizen interventions supported by analyses and legal representation that are usually lead by civil organizations. Their preparedness and arguments can have stronger effects on local environmental political decisions.

In extreme cases, issues regarded as serious enough can reach local referenda also by the initiation of the civil sphere. Valid and successful referenda have a binding effect, i.e. if inhabitants reject the investment of potential serious environmental risk, it cannot be realized.

In Hungary such successful local referenda impeded primarily the establishment of waste depositories and incinerators. Among them was the depository for low level and intermediate level radioactive wastes of the Paks Nuclear Power Station, which was not allowed to be constructed at the first site (Ófalu) by a referendum.

In the case study considered here, no active citizen interventions (protests, demonstrations) were organised – not even at the time when the air quality of the town was among the worst in the country. It was

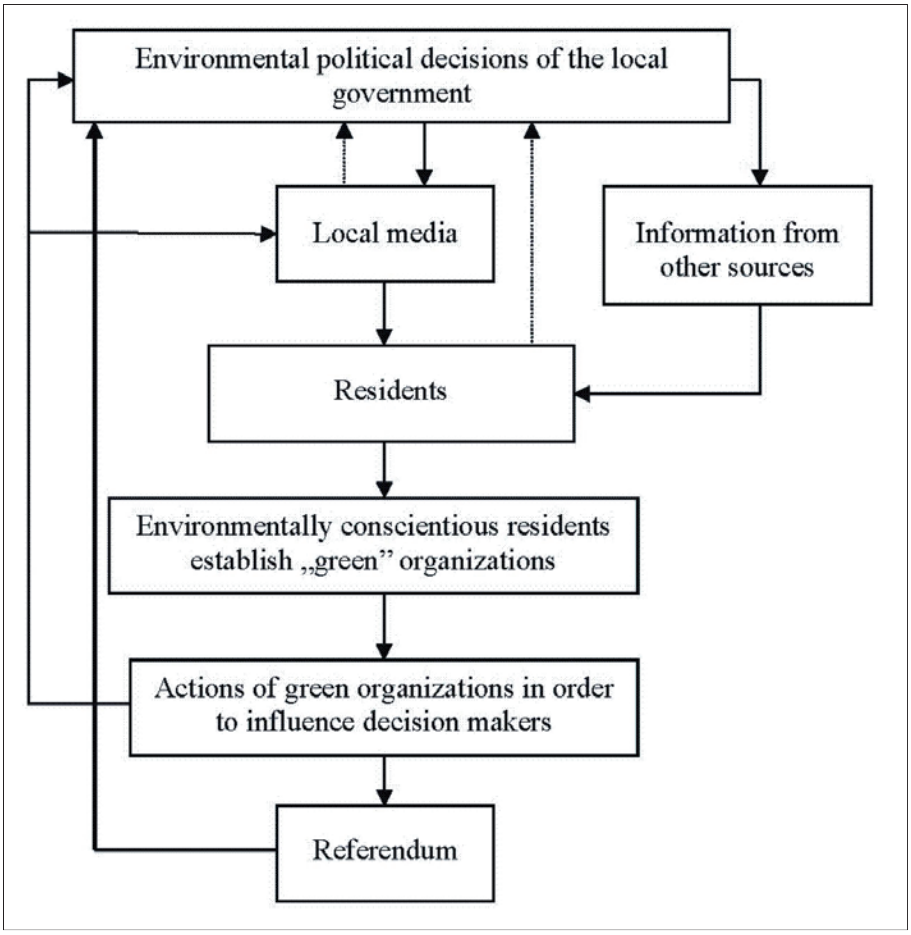

Fig. 10: Effects of residents and civil (green) organizations on local decision making (for explanation see text)
Dashed line: poor influence; Continuous thin line: moderate influence; Continuous thick line: binding influence

fortunate for the town that privatization following the regime change brought the re-development of a factory that was responsible for most of the air pollution in the town. This development resulted in the installation of environment-friendly technologies and the factory is committed to improve air quality, in partnership with the local government, civil organizations and inhabitants. Inhabitants' opinions reflect their regard for the environment protection activity of the local government as reasonable, and that of the civil organizations as particularly beneficial.

Regarding the relations between parties in the town, we believe that co-operation can be further improved by developing partnerships. The most important task is to improve information transfers to the inhabitants, in the hope of making them interested in developing the environment of the town and involving them in the immediate residential environment.

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Authors' addresses:

Dr. Attila KERÉNYI, DSc.
Department of Landscape Protection and Environmental Geography, University of Debrecen
Egyetem tér 1., Debrecen H-4032
e-mail: *kerenyi.attila@science.unideb.hu*

Anna MEGYERI-RUNYÓ
Apor Vilmos Catholic College
Konstantin tér 1-5., Vác, H-2600
e-mail: *megyerine@avkf.hu*

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MORAVIAN GEOGRAPHICAL REPORTS

Aims and Scope of the Journal

Moravian Geographical Reports [MGR] is an international peer-reviewed journal, which has been published in English continuously since 1993 by the Institute of Geonics, Academy of Sciences of the Czech Republic, through its Department of Environmental Geography. It receives and evaluates articles contributed by geographers and by other researchers who specialize in related disciplines, including the geosciences and geo-ecology, with a distinct regional orientation, broadly for countries in Europe. The title of the journal celebrates its origins in the historic land of Moravia in the eastern half of the Czech Republic. The emphasis at MGR is on the role of 'regions' and 'localities' in a globalized society, given the geographic scale at which they are evaluated. Several inter-related questions are stressed: problems of regional economies and society; society in an urban or rural context; regional perspectives on the influence of human activities on landscapes and environments; the relationships between localities and macro-economic structures in rapidly changing socio-political and environmental conditions; environmental impacts of technical processes on bio-physical landscapes; and physical-geographic processes in landscape evolution, including the evaluation of hazards. Theoretical questions in geography are also addressed, especially the relations between physical and human geography in their regional dimensions.

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The journal, Moravian Geographical Reports, publishes the following types of papers:

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Fig. 10: Outcrops of coarse-grain granites in the plots of farmland create the environment suitable for heaths and other acidophilous herb vegetation in the south-western part of the Bohemian-Moravian Highland (Photo P. Halas)

Fig. 11: Acidophilous herb vegetation became largely overgrown with woody plants in the 2nd half of the 20th century due to the absence of grazing. Species-rich herb fringes are promoted by regular mowing of roadside ditches – in front (Photo P. Halas)

Illustrations related to the paper by P. Halas