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INTERACTION BETWEEN HUMAN SOCIETY AND GEOMORPHOLOGY IN SPACE AND TIME BASED ON CASE STUDIES FROM HUNGARY

Final Report

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1. Introduction

It is well-known and generally accepted that human impact is more and more increasing everywhere in our natural environment, the geographical sphere. This statement is particularly relevant in the case of the Earth' surface both for geomorphological processes and land use/land cover (LULC) pattern: significance of human impact is a geomorphological factor equals to that of most natural ones (*Nir, D. 1983; Hooke, R.L., 1994, 1999, 2000*). Significance of human impact on the surface is increasing exponentially, and the process is driven by both population explosion and technical progress. Importance and scale of human impact is obviously proved by the fact that almost 30% of the Earth surface (approximately 150 millions square kilometres) is the scene of intentional and unintentional human activities, and these activities have, among others, fundamental geomorphological concerns. At the turn of the second Millennium area of plough-land and plantation covered 15 million square kilometres, area of grazing land was 35 million square kilometres, and the extent of built-up area reached about 2 million square kilometres (*Loh, J. & Wackernagel, M. 2004*); moreover, considerable part of forest of 38 million square kilometres is also undergone by more or less intensive human activity.

During the last one or two decades, study of human activities of the surface, including geomorphology and land use/land cover (LULC) has represented one of the main trends in geomorphological, landscape ecological and environmental researches; similarly, several important textbooks in this topic has been published (see, for example *Butzer, K.W., 1974; Kates, R.W. et al., 1990; Graf, W.L., 1996; Bennett, M.R. & Doyle, P., 1997; Goudie, A. & Viles, H., 2003;Haff, P.K., 2003; Simmons, I., 1993; Syvitsky, J.P.M. & Millimann, J.D., 2007; Slaymaker, O. et al., 2009*).

Study on human impact on the Earth's surface has a history of some decades in the Hungarian geographical literature. Amongst the pioneer papers, those of *Ferenc Erdősi* (1966, 1969) have to be mentioned in the first place. Then, environmental studies gave further boost to anthropic geomorphological studies (see, for example *Pécsi M., 1986; Erdősi F., 1987; Rózsa, P., 2007; Lóczy, D. & Pirkhoffer, E., 2009; Rózsa, P. & Novák, T., 2011*). During the last decades the Hungarian anthropic geomorphological researches have got to the international forefront which is symbolized by publishing the pioneer textbook concerning general review of human geomorphological impact (*Szabó, J. et al., 2010*).

Meanwhile, real boom in studies concerning LULC have proceeded, and many of the studies published in this topic dealt with human impact on the environment and provided relevant anthropic geomorphological information. Thus, for example, papers dealing with impact of historical land use changes on aquatic environment (*Nagy & Jung, 2005*), sediment fluxes (*Jordan et al., 2005*), soil properties and erosion (*Szilassi, P. et al., 2006, 2010*), damage of landscapes (*Lóczy, D. et al, 2007*), topography of urbanised area (*Lóczy, D.& Gyenizse, P., 2010*), landscape values (*Sallay, Á. et al., 2012*), floodplain area (*Varga, K. et al., 2013*), viticulture and vineyard reconstruction (*Nyizsalovszky, R. & Fórián, T., 2007; Dobos, A. et al., 2014*), and land-stability (*Demény, K. et al., 2016*), etc. have been published. Beside this, paper of *Péter Csorba* and *Szilárd Szabó* (2009) dealing with quantification of human impact by using hemeroby level, and that of *Gábor Demeter* (2006) on connection between LULC pattern and socio-economic needs must be mentioned.

Following *Dov Nir*'s (1983) classification concerning special aspects of anthropic geomorphology, to complete our research work three approaches were applied:

(1) Regarding the geomorphological approach we investigated the possibility of making a distinction between (i) 'anthropic' and 'semi-anthropic' process and forms; (ii) 'intentional' and 'unintentional' human geomorphological activities. Moreover, (iii) we intended to analyze human activities neglected so far from geomorphological point of view.

(2) Regarding the social-economic approach we analyzed the relationship between (i) different social-economic conditions and human geomorphological activities; (ii) geographical environment and LULC pattern; and (iii) social-economic development and potential anthropic geomorphological processes.

(3) Regarding the historic approach we studied (i) long-term changes in LULC pattern in different areas of various geographical environments; (ii) to draw some conclusions concerning relationships between anthropic geomorphology and LULC transformation based on case studies of different model sites, and (iii) to interpret the results in the context of social-economic history of Hungary.

To reach the aims of the project, the following first model sites characterized by different LULC pattern and natural conditions were designated in North and East Hungary: the Nagy Hill at Tokaj, Taktaköz, East Borsod Coal Basin, Bodrogköz as well as model areas in Sajó-Hernád Interfluve, Hortobágy and Nyírség. In the next phase fieldwork was performed including mapping, sampling and making other documentation. Determination of accumulation/erosion ratio was performed during fieldwork, too, but literature data was also taken into consideration. Relevant part of maps made in different historic periods (from the First Military Survey up till now) was digitalized and evaluated concerning main LULC categories in accordance with principal CORINE land cover categories.

In the next chapter results of our project are summarized according to the above mentioned approaches; therefore, results will not be presented for every studied area mentioned above, but the most characteristic one will be emphasized.

2. Results

2.1. Systematic remarks

To classified human geomorphological activities several approaches exist. Because of its complex topics, it is crucial to create a clear inner system for anthropogenic geomorphology. It is widely accepted that direct or indirect way of human geomorphological impact should be the basis of the classification. In general, the direct impact is intended, and the landforms created by these activities are easily recognizable. Direct anthropogenic impact may be primary when the main scope to create the form (e.g. terraces), or secondary if it just belongs to the human activity (e.g. waste dumps of mines). Indirect anthropogenic forms may induce new processes and create new forms, and in this case it is termed as qualitative; or it may influence natural morphological processes, and then is termed as quantitative. According to the morphological result of the human activity these forms may be excavation, aggradation (or constructive), and planation forms which are analogous to the natural erosion, accumulation and planation forms.

Obviously, anthropogenic landforms can be classified according to the types of human activities. The main human activities which modify the surface are: agriculture (including forest clearing), mining, riverbed and shore management, industry, transportation, urban construction, tourism and sport, and warfare. It seems to be logic to divide human activities into intentional/unintentional and direct or indirect groups, respectively. In general, forest management, grazing, pasturing, light and intensive ploughing can be regarded as unintentional, while mining, river and coast management, road and railway construction, town-planning, etc. as intentional activity. More generally, agrogenic activities (forestry, grazing, pasturing, tilling, etc.) are principally characterized by unintentional human activities, while montanogenic, industrogenic, urbanogenic and traffic interventions belong to the intentional one. Warfare and sport&tourism interventions may be both unintentional and intentional. Terracing as a special agrogenic intervention must be classified as intentional one. Reviewing the concerning literature, we concluded that ‘anthropic’ ‘semi-anthropic’ as well as ‘natural’, ‘semi-natural’, ‘artificial’ terms would rather be used for describing a certain form than for naming a type of landforms.

2.2. Anthropic geomorphological significance of municipal waste disposal

Management of waste production is one of the most important problems of environmental management. Although the amount of waste undergoing incineration and recycling is increasing, most of the collected waste, especially, municipal waste, is being deposited. Similarly to the European trend, in the last decade, both total quantity of municipal waste and deposited waste decreased in Hungary, but still more than 50% of the municipal solid waste was deposited in 2014. As Figure 1 shows, in 2014 more than 2 million tons of municipal solid waste was transported to the waste dumps. This amount is about one third of the total quantity of lignite extracted in Hungary in that year.

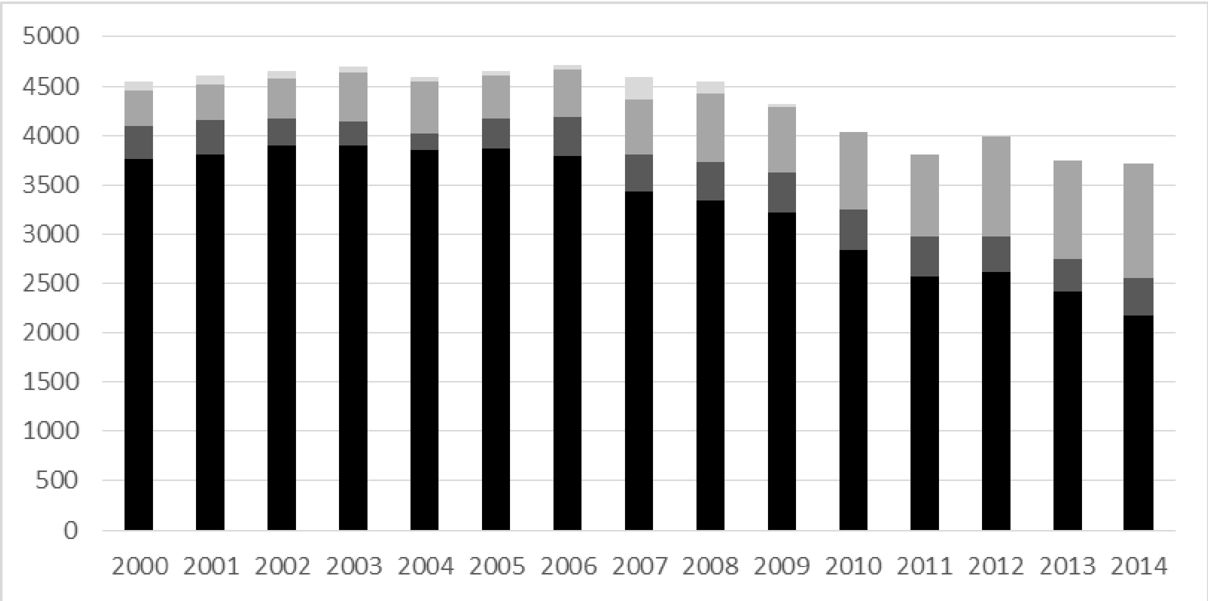

Figure 1. Change in quantity of solid municipal waste (black) and its treatment from 2000 to 2014 (Ktons)

According to the Waste Framework Directive, or Directive 2008/98/EC of the European Parliament and that of the Council, these old sites had to be managed and new regional deposits had to be built. Until 2014 more than 2500 sites were closed and partly reclaimed; 13 projects were finished, and up-to-date new deposits were constructed or old ones were updated. On the whole, in 2014 seventy-one waste deposits had permission to work in Hungary, more or less far from the bigger urban centres.

From geomorphological point of view, these deposits can be divided into two groups (*Rózsa, P. & Fazekas, I., 2016*):

(1) forming a hill on a (naturally or artificially) levelled surface or by ‘overfilling’ a (natural or artificial) pit (Figures 2 and 3); and

(2) refilling a natural valley (Figure 4).

Figure 2. Forming hill on a levelled surface - Gyál

Figure 3. Forming a hill by 'overfilling' a pit – Dunakeszi

Figure 4. Refilling a natural valley - Sajókaza

The planned total space of the regional waste deposits is circa 580 ha, that is 5.8 square kilometres which corresponds to almost one fourth of Lake Velence. This space is about one fifth of the surface covered by deposits in 2003. The average space of a deposit is about 8 ha. The total permitted quantity of waste to be deposed is about 98 million cubic metres, i.e. the capacity is sufficient for 50 years considering the recent annual waste production. More than 70% of the waste is to be transported to the type of forming an elevation on a level surface. Together with the pit and hill type this value increases to more than 85%. It is interesting that total planned height of the deposits would exceed the height of Kékes peak.

Regarding the spatial distribution of the geomorphological waste deposit types in the physical geographic macroregions, it can be stated that almost 50% of the deposits is located in the Great Hungarian Plain, while there are only two of them in the Little Plain. Not surprisingly, the pit-and-elevation and the valley type deposits occur in the North Hungarian and the Transdanubian Mountains, the Transdanubian Hills, as well as the hilly West Hungary regions (Figure 5).

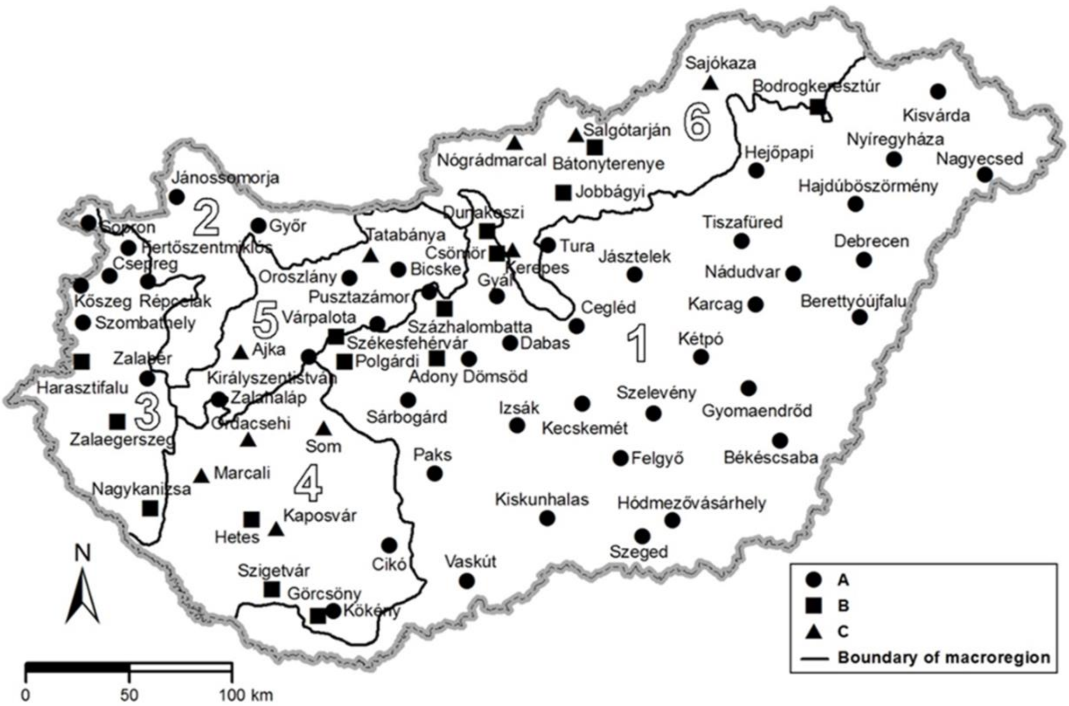

Figure 5. Geographical distribution of regional waste deposits of different geomorphological types. (Legend: full circle – forming a hill on a levelled surface; full square – forming a hill by overfilling a pit; full triangle – refilling a valley)

Data listed in Table 1 clearly show the correlation between the relief and the waste deposit types. In the flat terrains, 85% of the waste deposits is represented by the elevation type, and more than three fourth of the deposits of this type are in plains. The refilled valley type deposits occur in hilly and mountainous areas (60 and 40 %, respectively), while the pit-and-elevation types can be found in each type of relief with a decreasing tendency from the plains to the mountains.

Table 1. Cross-table of waste deposit types and relief types

			waste deposit type			Total
			Elevation	Pit&Elevation	Valley refill.	
relief type	plains	Number	36	6	0	42
		% within r. type	**85.7%**	14.3%	0.0%	100.0%
		% within wd. type	**78.3%**	40.0%	0.0%	59.2%
		% of Total	50.7%	8.5%	0.0%	59.2%
	hills	Count	4	5	6	15
		% within r. type	26.7%	33.3%	40.0%	100.0%
		% within wd. type	8.7%	33.3%	**60.0%**	21.1%
		% of Total	5.6%	7.0%	8.5%	21.1%
	mountains	Count	6	4	4	14
		% within r. type	42.9%	28.6%	28.6%	100.0%
		% within wd. type	13.0%	26.7%	**40.0%**	19.7%
		% of Total	8.5%	5.6%	5.6%	19.7%
		Σ	46	15	10	71

Landscape transforming effect of the regional waste deposits may be dramatic in plains, because these elevations appear as eye-striking anthropogenic elements, which are not similar to any natural or traditional forms. Moreover, these represent the dominant waste deposit type in the plains, where, as we have seen, most of the deposit sites were constructed. In the Great Hungarian Plain many of them may exceed the height of 25 m), and their average basic area exceeds 6.5 ha. Consequently, these huge elevations are strange anthropogenic elements in the rural landscape of the plains. Although these forms are created in rural areas, the waste material is dominantly produced in settlements, mostly in urbanized areas. Therefore, although these forms sometimes are far from cities or any settlements, they should be regarded as special transferred urbanogenic forms (*Rózsa, P. & Fazekas, I., 2016*).

2.3. <u>Anthropic geomorphological significance of terracing</u>

In Hungary terraces were built mainly for vine production in the hilly area of wine regions. The study was made in the Nagy Hill, where the first written record mentioning terraces is dated from the early 17th century. Terraces were maintained and cultivated until the middle 20th century (Figures 6 and 7).

Figure 6. Old stone-walled terraces on Nagy Hill

Figure 7. Earth-terraces on Nagy Hill

Mapping this type was possible by using aerial photographs from different time-sections because maps do not depict these constructions. Since abandoned terraces are mostly overgrown by dense vegetation remote sensed data were applicable rather from the early succession phases, or in aspects without foliage. After the retaining walls were detected and mapped by remote sensed data, the spatial density ($m \cdot ha^{-1}$), height (m) and width (m) of retaining walls, and width of terraces (m) were measured in the field. Latest vineyard plantations (in the last 60 years) were settled without construction of stone walls, but they required earth construction works in similar volume. The volume of material moved by the terracing processes was calculated based on the shape and extension of terraces. In the case of older terraces, the amount of the stone material was also added, where the mean density of dry constructed stone walls was regarded as constant, 2 $t \cdot m^{-3}$, as it is usual in building practice. Density of filling material of terraces was regarded to be 1.3 $t \cdot m^{-3}$.

Beside the above mentioned processes terrace construction, levelling and other significant earth construction works dominate the surface development. Extension of the terraced slopes by dry constructed retaining walls occurring in the southern side of the Hill is 129 ha (6.1%). The mean distance of retaining walls, where they occur at all, is 7.4 metres, their mean spatial density is 632 $m \cdot ha^{-1}$; based on 304 cases measured in the field, the mean height and the mean width is 1.30 and 0.93 m, respectively. Using these data the mass moved by terrace construction could be estimated to be 6.19 $t \cdot ha^{-1} \cdot yr^{-1}$. For levelling the slope between the retaining walls significant mass of material should be moved, too; calculating with the data above and with a constant density of soil ($1.3\ t \cdot m^{-3}$) its rate is $14.95\ t \cdot ha^{-1} \cdot yr^{-1}$. It means that the rate of mass moved by construction of stone-walled vineyard terraces could be estimated to be $21.14\ t \cdot ha^{-1} \cdot yr^{-1}$ including slope-leveling and wall construction as well. On further 177.5 ha (8.4%) levelled vineyards, without retaining walls could be found. Size of these earth-terraces is similar to that of the older ones with stone walls, and the concerning material-deposition rate can be regarded as $14.95\ t \cdot ha^{-1} \cdot yr^{-1}$. In total, $18.04\ t \cdot ha^{-1} \cdot yr^{-1}$ could be taken into account as mean material transportation rate for the two different types of terraced slopes (*Novák T. & Incze J., 2014*).

<u>2.4. Qualification and quantification of human geomorphological activities – case studies</u>

2.4.1. Tokaj Nagy Hill

The scale of the grade of human influence could widely vary ranging from natural surfaces not affected by any anthropogenic process to surfaces completely controlled by human society, where natural geomorphological processes are intended to be eliminated, or to be compensated by constant intervention. Between these two extremes there are areas where natural geomorphological processes are modified by intentional or unintentional human activities. Study for identifying, localizing and quantifying anthropogenic geomorphological processes was performed on the Tokaj Nagy Hill, the emblematic site of the World Heritage Tokaj Wine Region Cultural Landscape, a typical European hilly cultural landscape with traditional diverse land use structure. The aim of the study was to localize and identify diverse anthropo-geomorphologic processes shaping the actual surface. Furthermore we aimed to quantify and compare the volume of natural and anthropogenic geomorphologic processes functioning in a typical cultural landscape with diverse land use history and human activities. The comparison focuses on the single aspect of geomorphologic processes, namely material transportation. If not the accurate amount, the magnitude of the processes could be estimated, and it also makes possible a comparison between natural and anthropogenic processes. Therefore, estimated data of natural processes were applied and data of former field measurements from reference works recalculated and expressed by their rate of mass deposition ignored their spatial complexity and temporal variability. This kind of abstraction allowed to distinguish different areas according to the degree of human influence, and to compile an anthropo-geomorphologic map about the Nagy-Hill.

To compare natural and anthropogenic processes first of all total amount of natural, or quasi-natural background-processes were expressed as material-deposition rate ($t \cdot ha^{-1} \cdot yr^{-1}$), and were estimated for the whole study area. The area was divided into homogeneous spatial units, in which the material deposition has the same order of magnitude.

In the second step amount of anthropogenic processes was calculated. The relevant processes were grouped in process-combinations, and homogeneous spatial units were mapped by the dominant anthropogenic processes. To establish the spatial pattern of dominant anthropogenic processes land use, data of the 1st, 2nd, and 3rd Military Surveys, topographic maps, aerial photographs and satellite images were used. Based on cartographic land use data the duration of surface forming anthropogenic processes were also established, as far as it was possible. Maps were converted into the same projection (EOV) with Quantum GIS 2.12., remote sensed data were first orthorectified, for that Erdas Imagine 8.5 software was applied. All land use data of maps, aerial photographs and satellite images were uniformized by categories (forests, grasslands, plough lands, vineyards, quarries, erosion gullies and built up areas were distinguished) and vectorized with ArcGIS 10 software. From overlaid and cross-sectioned maps an anthropo-geomorphological map was compiled, in which to every spatial unit the most effective anthropogenic process was ordered, which even appeared during the studied time-interval.

To express the degree of anthropo-geomorphologic influence on the landscape the concept of the ratio of anthropo-geomorphologic transformation (r_{AG}) was introduced. It is defined as follows:

$$(1)\ r_{AG} = V_A \cdot V_N^{-1}$$

where, V_N = magnitude of material transported by natural processes ($t\ ha^{-1} \cdot yr^{-1}$); and V_A = magnitude of material transported by anthropogenic processes ($t\ ha^{-1} \cdot yr^{-1}$).

The natural geomorphologic components of forming the surface of the Nagy-Hill are sheet erosion, soil creeps, linear erosion, and accumulation of eroded sediments, dust deposition and dust emission. For the investigated last near 300 years relevant components of anthropogenic geomorphic processes have been accelerated erosion due to deforestation, grazing and fire (Vae); tillage erosion of cultivated areas (Vate); landscaping, terracing (Vat); gully development due long-time cultivation (Vag); material loss by quarrying (Vaq), and built-up or sealed area (Vam). Consequently,

$$(2)\ VA = Vae + Vate + Vat + Vag + Vaq + Vam$$

Results of our calculations are listed in Tables 2 and 3.

Table 2. Mass deposition rates and spatial extension of dominant geomorphologic processes on Tokaj Nagy-Hill

Geomorphologic processes	Magnitude of mass deposition rate (t·ha–1·yr–1)	Area dominated by the process within study area (%)
VN (natural)	<1	2.57
Vne (natural sheet erosion)	$10^{-1} – 10^{0}$	2.57
Vng (natural gully erosion)	$10^{1} – 10^{2}$	n.d.
VA (anthropogenic)		89.79
Vaq (excavation)	14742	4.34
Vag (accelerated gully erosion)	130	3.42
Vate (tillage erosion)*	15.13	62.3
Vat (terracing)	18.04	14.45
Vae (accelerated sheet erosion)*	$10^{-1}– 10^{0}$	5.27
Human geo-environment (processes blocked, or compensated)	n.d.	7.64

Table 3. Magnitude of mass moving rates and spatial extension of selected geomorphologic processes on Tokaj Nagy-Hill

Magnitude of mass deposition rate ($t·ha^{-1}·yr^{-1}$)	Geomorphologic processes
$10^{3} – 10^{4}$	Vaq (excavation)
$10^{2} – 10^{3}$	Vag (accelerated gully erosion)
$10^{1} – 10^{2}$	Vate (tillage erosion) Vat (terracing) Vng (natural gully erosion)
$10^{0} – 10^{1}$	Vae (accelerated sheet erosion)
$10^{-1} – 10^{0}$	Vne (natural water erosion and sedimentation)
$10^{-2} – 10^{-1}$	Vne (natural wind erosion and sedimentation)

Overlaid, cross-sectioned and reorganized land use patterns made it possible to compile the anthropo-geomorphological map of the study area (*Incze, J. et al., 2013*). Based on the analogy of 'hemeroby' concept, which expresses the degree of human influence on ecosystems, our approach could be denominated with the term of 'hemeromorphy' which is suitable to express the degree of human influence on geomorphosystems (complexes of surface forming processes) independently from their geomorphic process combinations, relief and climate. The smallest landscape units, which are homogeneous according to their hemeromorphy can be referred as hemeromorphotops (*Novák, T.J. et al, 2013*) (Figure 6).

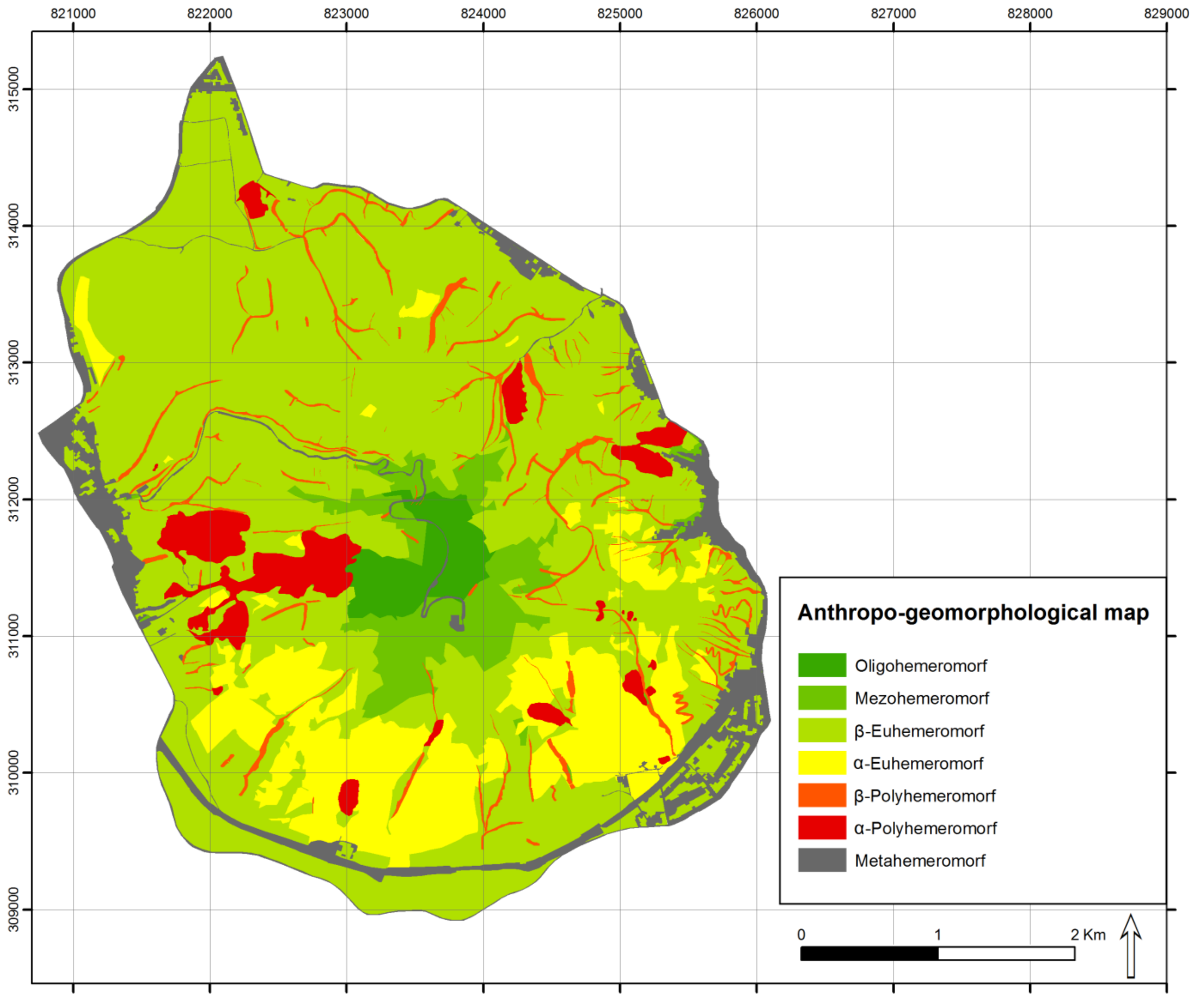

Figure 6. Anthropo-geomorphological map of Nagy Hill based on 'hemeromorphy' concept

2.4.2. East Borsod Coal Basin

The approximately 500 km^2 intra-montane hilly area of the East Borsod Coal Basin is rather an economic geographical-geological than a physical geographical region. From physical geographical point of view, East Borsod Coal Basin is the area of the hills in both sides of the Sajó River that belong to catchments of small affluents of the river. Its central part is the Sajó Valley Basin microregion which divides it into two parts: the southern one is actually formed by northern part of Tardona Hills and Uppony Mountains, and the northern one is formed by southern part of Putnok Hills microregions, respectively. These microregions can be regarded as foothill areas dissected by watercourses.

The Palaeozoic-Mesozoic basement is covered by mass movement susceptible Miocene fluviatile aleurite-sand-clay with intercalation of 5 mineable (and further 50 adjacent) seams (Salgótarján Lignite Formation). Settling progressed from the river valley towards the hilly areas, however, because of low productivity soils, as well as erosion and mass movement susceptibility on the slopes only small villages occurred until the mid-19th century. This pattern was fundamentally transformed by coal mining providing energy basis for heavy industry founded in the region. Consequently, population and extension of the settlements as well as extension of tillage showed quick growth (*Sütő, 2013*).

Land use indicated by the First Military Survey, was regarded as the ancient traditional land use (Figure 7A). The East Borsod Coal Basin was dominated by forests (more than 40%), but extension of arable land was also significant (almost 30%). The Second Military Survey indicates only moderate changes in land use and land cover for the East Borsod Coal Basin area. By the time of the Third Military Survey, moderate increase of arable lands and decrease of forests, continued. As a result, ratios of arable land and forest were equalized. As Corine Land Cover 2000 indicates that some further remarkable changes happened to land use and land cover pattern. In the East Borsod Coal Basin forests represent the largest land cover type, their ratio almost reaches 40%. Moreover, area of artificial surface dramatically increased; increase in its ratio was almost fivefold. At the same time extension of arable lands significantly decreased, and it reduced two-third of its former value (Figure 7C).

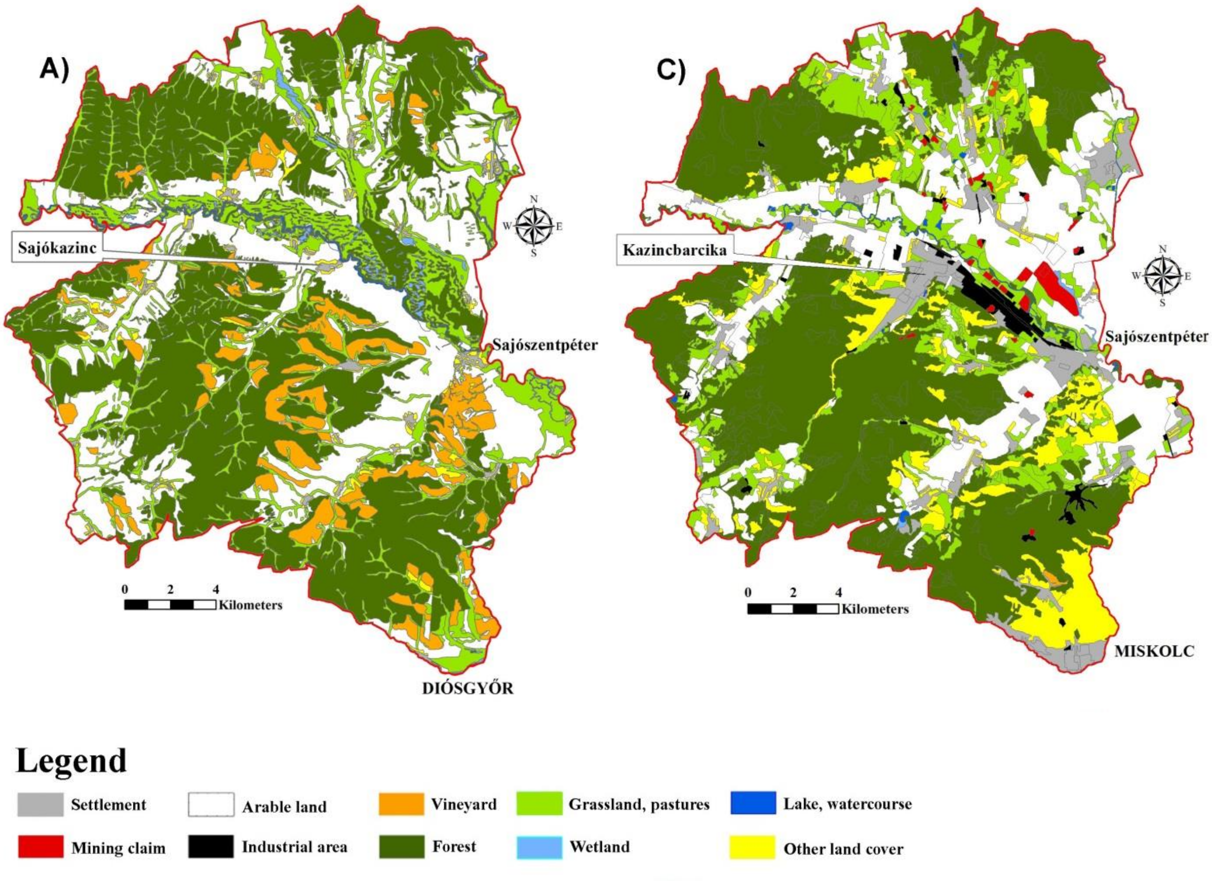

Figure 7. Land use and land cover pattern at the time of the First Military Survey (A) and the second Millennium (C)

To estimate montanogenic relief disturbance a new method was developed (Sütő, 2013). Values of vertical relief changes were calculated for each montanogenic field objects, and then their absolute values were summed, that is:

$$(3)\ B_d=\ln(|M_t|+|M_h|+|M_{bt}|+|M_{bv}|+|M_e|),$$

where B_d: mining disturbance; M_t: thickness of the extracted bed; M_h: elevation of waste dump; M_{bt}: mining plant (used average: 1 m); M_{bv}: mining railways (used average: 1 m); and M_e: elevation or deepness of other mining objects summarised on given surface (in metre).

The surface affected by material transport of mining origin in the East Borsod Coal Basin south of the Sajó River is more than 76 km^2. It means that during the past 250 years 5.2 m thick material belonging to every point of 27% of the study area was transported. According to the disturbance map in the region, the largest rate of transformed surfaces is located in the catchment area of Pereces and Lyukó Brooks. According to the disturbance index calculated by using Equation (3), 68-70% of the area underwent mining disturbance as a result of long-term coal mining exploiting four coal seams and of the fact that mining extended in time due to the closeness of the iron works in Miskolc-Diósgyőr (Figure 8).

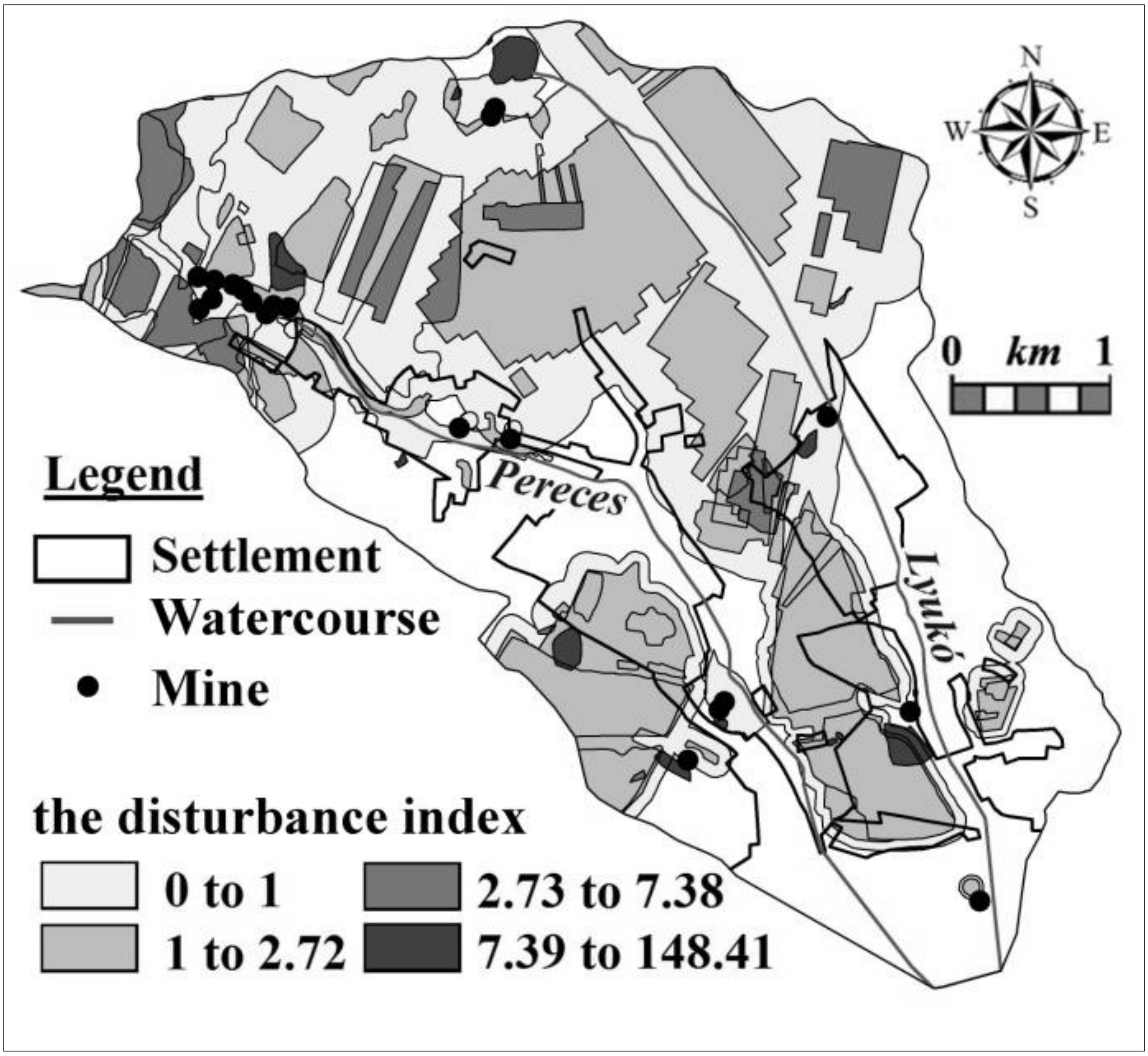

Figure 8. Disturbance map of the catchment area of Pereces and Lyukó Brooks

2.5. Mining and settlement development – a case study from northern part of the East Borsod Coal Basin

Settlements are built for centuries or more, however, pattern of their network is permanently changing according to modification of economic circumstances. During the last two or three centuries, the settlement network pattern in the East Borsod Coal Basin has suffered some sweeping changes. Considering that mining has played a principal role of recent landscape character of the area, we introduce how the temporal change of coal mining was followed by spatial change of settlement network. To demonstrate this relationship field observations as well as geo-informatic evaluation of mining and topographic maps concerning land use, direct and indirect mining areas and extension of the built-up area of the settlements were performed. Moreover, data concerning land use, population, number of houses, and mining production were statistically evaluated.

Northern part of the East Borsod Coal Basin was chosen for the study, since mining settlements located in the area have quite similar historical and geographical background. Due to the fact that these settlements belonged to the once Szuha Valley Coal Mining Works, more or less detailed data series for coal production are available.

Intensity of exploitation of coal seams can be divided into three periods In the first one increase in coal production was due to economic boom following the Austrian-Hungarian Compromise (1867), since the developing heavy industry and rapidly growing railway system requires more and more coal. The second phase began after World War II (Figure 9), due to industrialization of the country, in general, and in the Borsod Basin, in particular. Mining was intensified, and further coal fields were discovered and yielded. The latest development of coal mining in the area was performed in the 1960s and 1970s. This fact is reflected by increase in houses shown by Figure 10. From the late 1970s coal mining started a rapid decline, and until the mid-90s coal mines were closed.

Changes in population in the settlements of this mining microregion show that there is some correlation of population number and coal production of mines of the close area of the given settlements (Figure 10). From the 1970s, after the start of crisis in coal mining population of most settlements have decreased, specially, in the case of the so-called mining villages, where coal mining played a fundamental economic role. Edelény, Izsófalva and Múcsony are exceptions; either, because of more diverse economy (Edelény), or because of their transportation geographic position and the effect of latest developments.

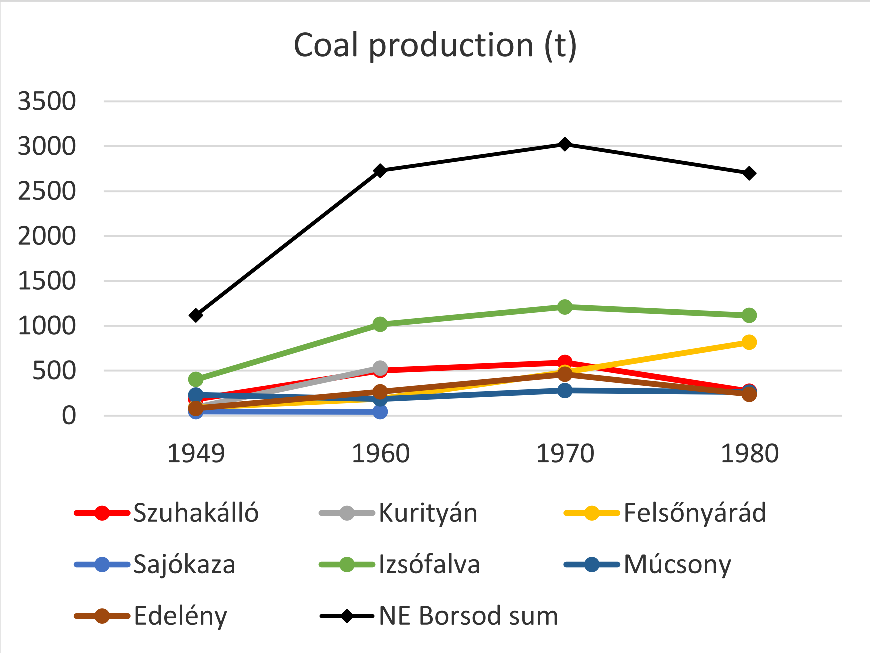

Figure 9.Coal production of Szuha Valley Coal Mining Works after WWII to 1980.

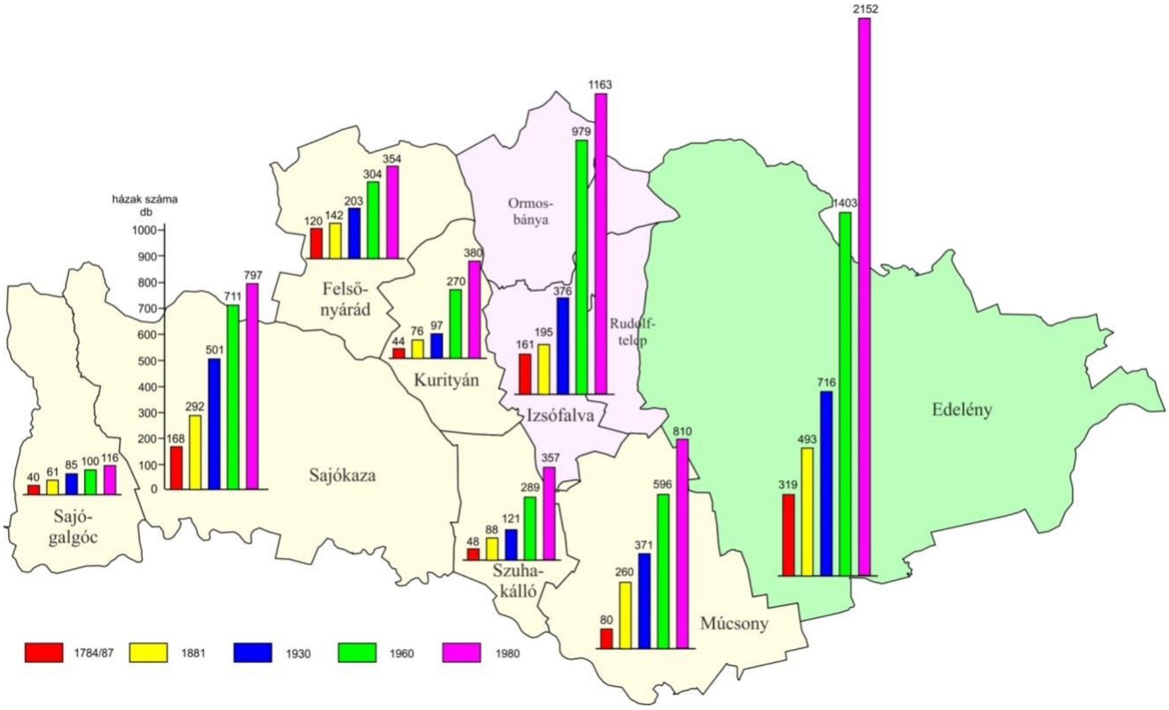

Figure 10. Changes in number of houses in the settlements of the mining microregion

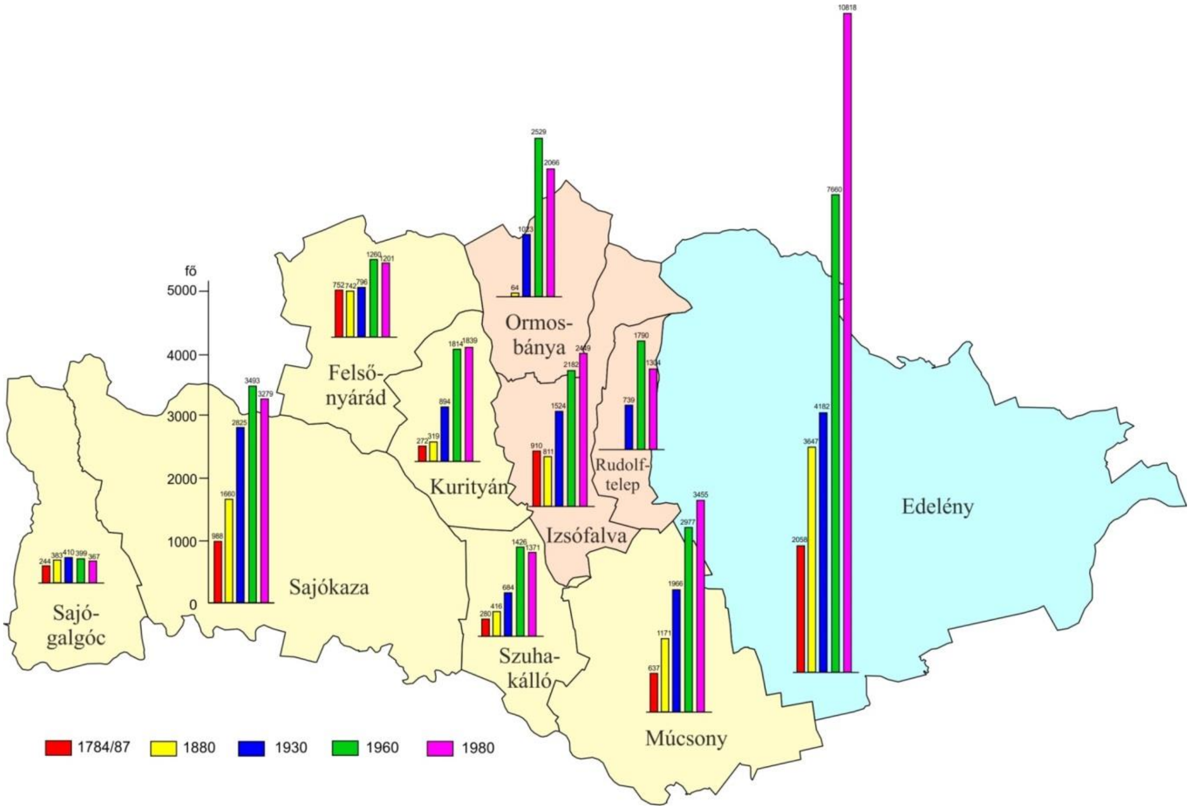

Figure 10.Changes in population of the settlements of the mining microregion.

Changes of mining production had an effect on land use pattern of the settlements, too (Figure 11). According the long-term changes in land use pattern, settlements can be divided into two parts. First, there are settlements where land use pattern has not been radically changed by coal mining. In the territory of the settlements belonging to this group mining production was relatively low (Sajókaza) or short-termed (Sajógalgóc). In the case of Edelény, its large extension explains it.

Settlements characterized by radical long-term changes in the land use pattern belong to the second group. Considerable increase in built-up area, and radical decrease in extension of forests and/or grassland are characteristic for them. It is possible that the obvious decrease of built-up area in land use pattern for Szuhakálló belonging to this group may be a sign of the next new period of land use pattern development.

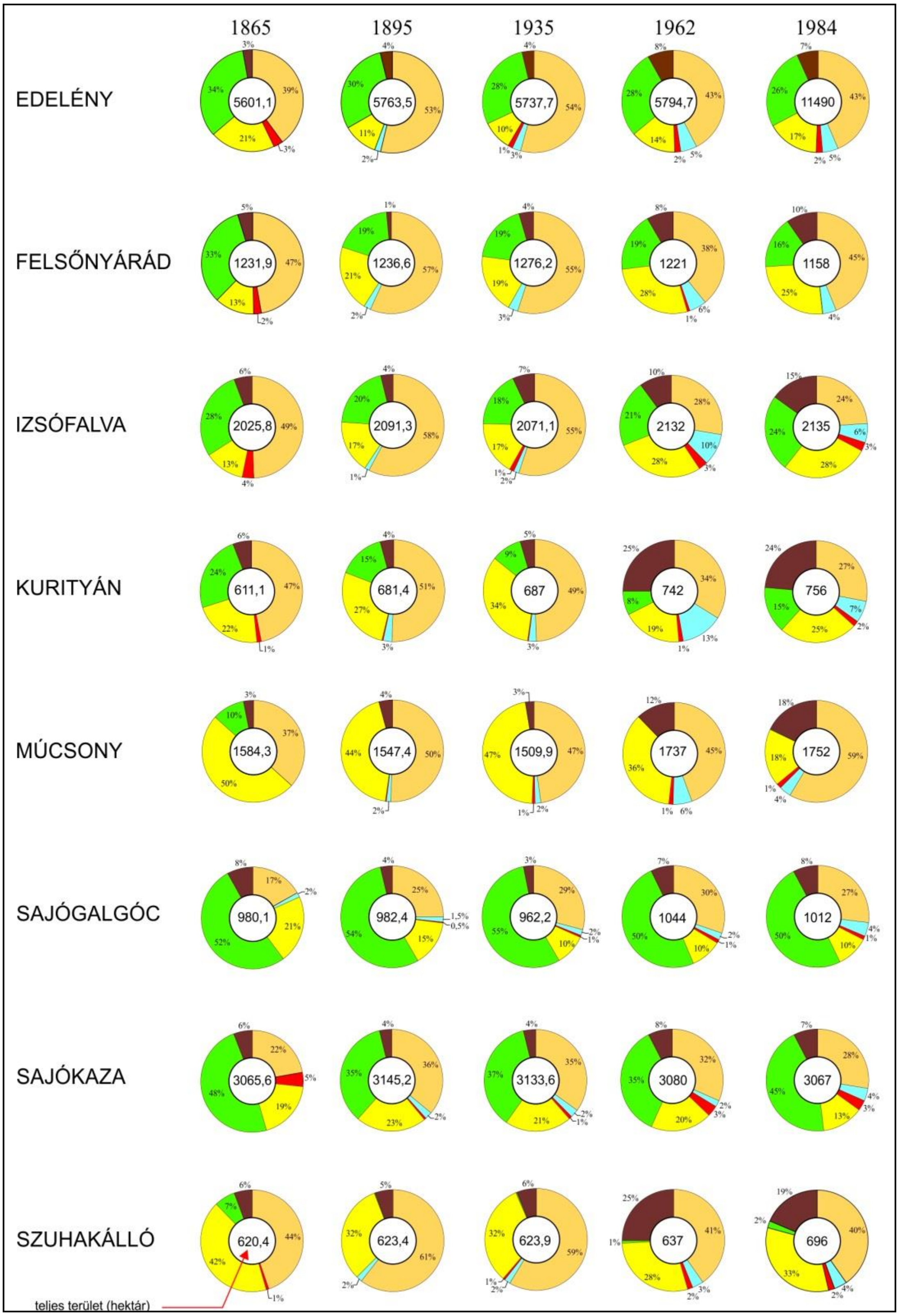

Figure 11. Changes in land use pattern for the settlements of the coal mining microregion (Legend: beige – plough-land; blue – garden, orchard; red – vineyard; yellow – grassland; green – forest; brown –roads, built-up areas, railways, industrialized area, etc.)

Our study revealed that there is correlation between coal mining activity (and its intensity) and the built-up area of the settlement (*Sütő L. et al., 2015*). Similarly, positive correlation between coal production and population number of the settlements. Moreover, increase in mining activity implied increase in number of houses, and the increment has endured after the decline of mining. Coal mining more or less transformed the traditional land use pattern, however, after its termination the traditional land use pattern may be restored. As a summary, it can be concluded that although coal mining activity may have significant short-term effect on population and land use pattern of settlements involved, coal mining itself does not improve long-term sustainable development of the settlements.

2.6. Long-term transformation of land use pattern resulted by changes in human activities – a comparative study

Study on long-term changes in land use is quite important from several points of view. Studying the long-term development of land use we can understand dynamics and transition of the landscape and the land systems, consequently, these researches can be directly used in landscape planning and natural conservation.

In the formerly socialist countries fundamental changes have occurred in land use pattern after the collapse of the political regime. In this study of three areas of different dominant landscape types located in Borsod-Abauj-Zemplén county is presented, which have undergone different human disturbances: on the Nagy Hill at Tokaj viticulture has been the dominant land use for centuries; in the Taktaköz tillage has represented the main land use type for more than one century; and in the East Borsod Coal Basin coal mining was the main landscape forming factor during the 20th century.

Aim of our recent study was to compare different types of human interventions on the LULC during the last 250 years: (1) to identify and determine the changes in land use pattern in the study areas in the last 250 years; (2) to trace driving forces of the changes in land use; (3) to suggest landscape-planning implications of long-term changes in land use pattern.

Comparison of the model areas was made by using censuses (such as the *Investigatio* compiled for the Maria-Theresa's *Urbarium* in second half of the 18th century) and mining records and maps. The relevant sheets of the military surveys were also used. To study the recent LULC pattern the Corine Land Cover 2000 on the scale of 1:50000 (CLC2000) digital map of Hungary was used. Maps of different projections and topics were converted into common projection system (EOV) with Quantum GIS 2.12. To trace the changes, land use data of the maps were uniformized by categories (settlement, mining, industrial area, vineyard, arable land, grassland, forest, wetland, water course or lake) and vectorized with ArcGIS 10 software.

To estimate human transformation of landscapes in a given period LULC categories were classified into 6 (oligo-, meso-, α-eu-, β-eu-, poly-, metahemerobe) levels, and ratio of the LULC categories were weighted by multiplying factors (*Csorba, P.& Szabó,Sz., 2009*).

Due to the different natural and environmental conditions land use patterns of the studied areas differed from each other even then. In the late 18th century almost 85% of the area of Nagy Hill was used as vineyard; approximately 50% of the Taktaköz was grassland, and wetlands also represented considerable land use; more than 40% of the East Borsod Coal Basin was covered by forests and arable land represented further almost 30% (Table 4).

The Second Military Survey indicates only moderate changes in land use for the East Borsod Coal Basin. In the case of Nagy Hill, however, significant decrease in vineyards (almost 25%), and almost 10% increase in extension of arable land and grassland per each can be observed. In the Taktaköz wetland area seriously reduced to one third of its former ratio, and extension of grassland increased by more than 10%.

By the time of the Third Military Survey, significant changes in land use had occurred for Nagy Hill: vineyard area reduced further (10%), and ratio of arable land considerably increased. In the Taktaköz ratio of arable lands increased by two and a half times, and it became the dominant land use in the microregion. At the same time, extension of grassland almost halved. In the East Borsod Coal Basin area continued the moderate increase of arable lands and decrease of forests. As a result, ratios of arable land and forest were equalized.

Corine Land Cover 2000 indicates some further remarkable changes from the late 19th century to the turn of the Millennium. In the Nagy Hill extension of vineyards reduced to one third of the total area of the microregion, and tended to concentrate on the lower part of the slopes. Ratio of arable lands practically halved. At the same time, ratio of forest shows six-fold increase. In the Taktaköz ratio of arable lands exceeded 60%, and extension of grasslands was more than halved. In the East Borsod Coal Basin extension of forests begin to increase again, and area of artificial surface dramatically increased, its ratio was almost fivefold. At the same time, extension of arable lands significantly decreased.

Table 4. Land use pattern of the study areas in the investigated period

LULC	Nagy Hill				Taktaköz				EBCB			
	1	2	3	4	1	2	3	4	1	2	3	4
	%	%	%	%	%	%	%	%	%	%	%	%
Artificial surface*	3.8	6.2	8.1	8.1	1.3	2.2	2.4	3.9	1.1	1.1	2.0	9.5
Arable land	2.8	12.8	20.5	11.0	16.4	17.8	45.8	61.6	28.8	28.9	33.4	22.8
Forest	6.5	3.5	4.9	29.4	6.0	5.0	4.8	7.9	41.5	38.7	34.2	39.7
Grassland	2.7	12.0	12.7	13.9	49.1	61.2	39.4	15.4	17.6	20.1	19.3	22.3
Vineyard	84.2	60.7	50.8	35.4	0.0	0.0	0.0	0.2	8.0	6.6	6.7	<0.1
Waterflow, still water	0.0	0.0	0.0	0.1	4.5	6.7	5.8	4.9	0.6	0.6	0.6	0.5
Wetland	0.0	0.0	0.0	0.0	22.7	7.1	1.8	4.3	0.8	1.3	1.4	0.1
Other**	0.0	4.8	3.0	2.1	0.0	0.0	0.0	1.8	1.6	2.7	2.4	5.1

1.First Military Survey; 2. Second Military Survey; 3. Third Military Survey; 4: CLC2000
**including settlements, industrial areas, quarries, mining claims*
***orchards, gullies, complex cultivation, etc.*

Although all the three study areas can be regarded as rural country of peripheral geographical situation, due to their different natural conditions and socio-economic background their LULC differed from each other as early as the 18th century. Later, during the last two and a half centuries different human impacts affected these territories. Degree of human influence on natural environment is usually characterized by using hemeroby scale. Aggregate hemeroby values for the study areas in the different investigated periods are listed in Table 5.

Table 3. Changes of hemeroby values for the study areas

year	Nagy Hill	Taktaköz	EBCB
1783-84	754	217	280
1856-60	677	245	277
1883-84	652	310	301
1999	514	361	340

In the case of Nagy Hill at Tokaj between the First and the Second Military Surveys degree of hemeroby decreased (Figure 12) due to the significant increase of arable land and grassland area against vineyards. By the end of the 19th century hemeroby values moderately decreased due to further loss of vineyard area and growth of the extent of arable lands. In the late 1880s and early 1890s devastating phylloxera epidemic swept over the Hungarian vineyards. As a consequence, famers tended to give up cultivating the vinery. Moreover, the rapidly developing industry offered possibility of employment for the agricultural labour surplus. After the phylloxera epidemic, however, human disturbance gradually decreased because of forestation and an increase of shrubby-bushy areas. Simultaneously, extension of both vineyards and arable lands considerably decreased. Accordingly, hemeroby value for the microregion considerably decreased mainly due to remarkable increase in forest. Peculiarly, hemeroby values and ratio of artificial surface has changed oppositely. This suggests that direct and intentional human impact concentrated in the relatively small area of two settlements (Tarcal and Tokaj) located in the foothill area, and changes in hemeroby values were basically controlled by changes in the extent of vineyards, arable lands, grasslands and forests.

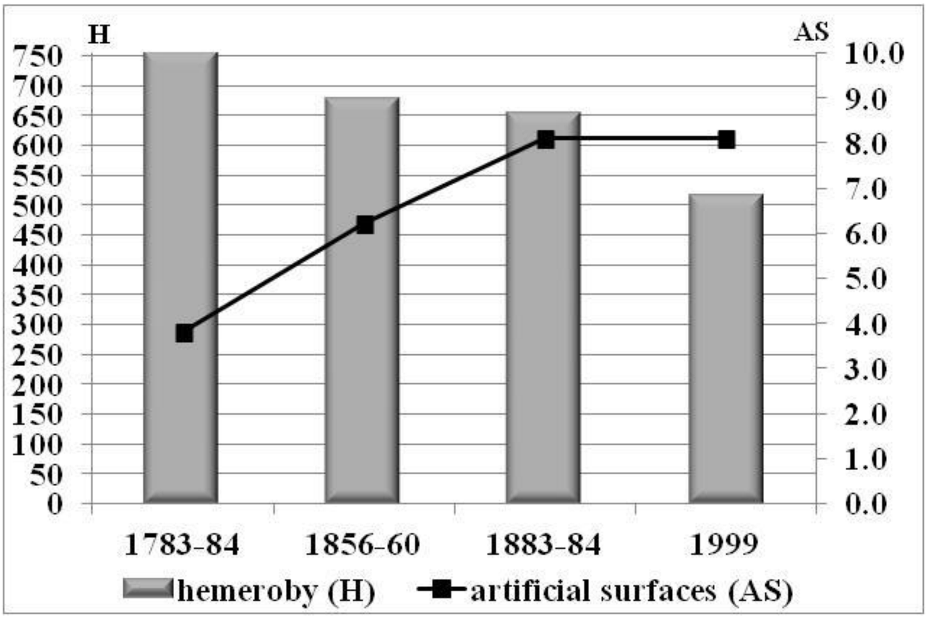

Figure 12. Changes in values of hemeroby and ratio of artificial surfaces for the Tokaj Hill

In the second half of the 18th century almost one-fourth of the Taktaköz plain was wetland flooded by Tisza River and Takta Brook year by year; arable land represented less than one-sixth of the area. Moreover, ratio of artificial surfaces (settlement, roads, etc.) hardly exceeded 1%. Consequently, the calculated hemeroby value for the area is as low as 217 (Figure 13). Although some decrease in wetland area and increase in grassland can be observed, the semi-natural character was retained until completion of river regulation and inland water protection works in the second half of the 19th century. Since the area has become practically to be prevented from floods, the ancient landscape and the traditional land use had to be changed: floodplain management and pasturing was replaced by arable farming; this tendency continued during the 20th century, and a relatively homogeneous agricultural landscape has been formed. Hemerobic conditions declined parallel to gradual extension of arable lands. Because of increase in maintenance capability of the area coming from river regulation population of Taktaköz doubled within some decades (*Dobány Z., 2014*). Since then, however, increase of population and that of artificial surface became slow.

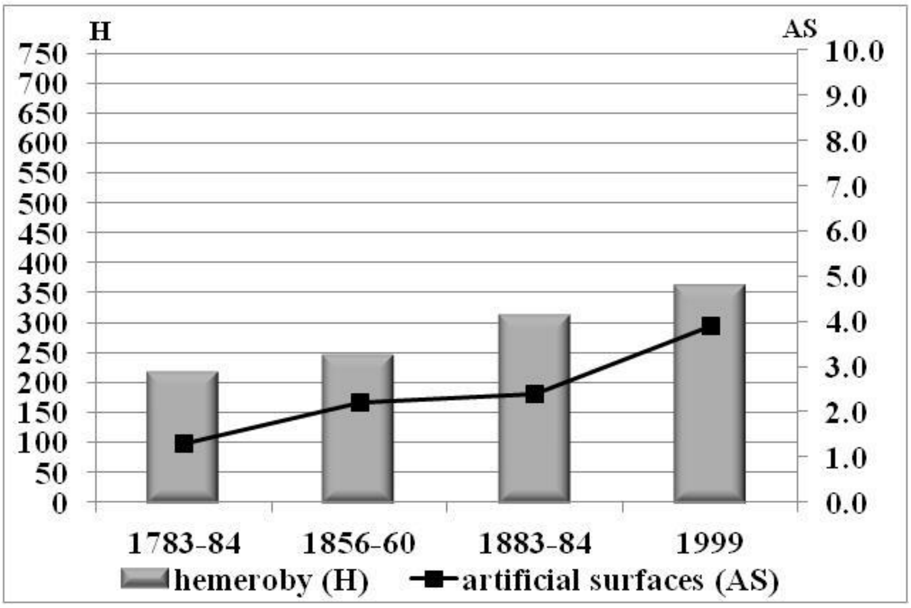

Figure 13. Changes in values of hemeroby and artificial surfaces for the Taktaköz

From the late 18th to the end of the 19th century land use pattern in the area of the East Borsod Coal Basin moderately but progressively changed. Extension of forests decreased from more than 40 to less than 35% while that of arable lands increased from 28.8 to 33.4%; although ratio of artificial surfaces doubled, its value was as low as 2%. Consequently, hemeroby level hardly increased during that period (Figure 14). Initially, coal mining did not represent significant impact on the surface and on land use. Mining activity operated dominantly under the surface, and increase in built-up area of the settlements was quite moderate.

From the late 19th century, however, a fivefold increase in artificial surface can be observed due to foundation of the dominantly coal mining based heavy industry, however, this industrialization process basically concentrated in the southern part of the Sajó Valley microregion. Moreover, mainly spontaneous reforestation in the hilly area can also be observed: ratio of forests has approximated the value in the late 18th century. As a consequence, considerable increase in artificial surface was followed by quite moderate increase of hemeroby level.

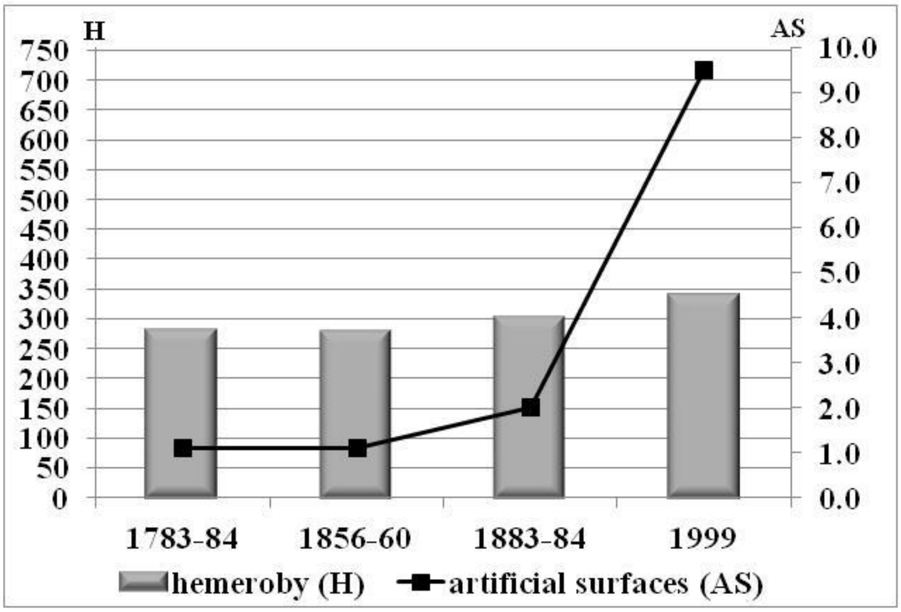

Figure 14. Changes in values of hemeroby and artificial surfaces for the EBCB

Study on transformation of land use pattern may also have landscape planning implications, since prevention or reconstruction of historical landscape must be supported by anthropo-geomorphological and landscape metric analyses based on historical geographical studies.

In the case of the Nagy Hill at Tokaj, viticulture as the dominant human impact of the landscape has history of several centuries, and the name of 'Tokay wine' became a world-famous brand. Therefore, increase of human viticultural activity would be required and replantation of the once famous abandoned vineyards would be the most reasonable and advantageous purpose. Conflicts between the economic operators and the natural preservation organizations may emerge. Far-seeing landscape planning, however, is able to take nature and extent of human disturbance into consideration, and focusing on anticipation and negotiation (*Dobos, A. et al., 2014; Hersperger, A.M. et al., 2015*) disagreements may be eliminated or, at least, reduced.

Arable land dominated land use pattern has been characteristic for the landscape of Taktaköz for more than a century, and it may represent cultural heritage and landscape structure elements (*Altieri, M.A., 2004*); consequently, one possible landscape planning aim would be to prevent and sustain tilling of arable land. Due to topographic and hydrographic conditions, however, some elements of floodplain management could be resumed in fallow lands and arable lowlands of poor quality meadow soil.

Economic prosperity of hilly terrains of the East Borsod Coal Basin was supported by coal mining, and mining closure was followed by rapid economic decline leading to a kind of autarchy, again. Although there are some projects intending to re-open some closed coal mines, landscape history of the area suggests that coal mining itself does not improve long-term sustainable economic development of the area. Because non-visible consequences of subsurface coal mining represent restraining factors in land use development, re-vitalisation of traditional hilly farming and forestry may play important additional role in the low populated inner hilly areas (*Sütő L., 2013*). Spontaneous reforestation should be followed by planned afforestation focusing on both timber industrial and ecological aspects would be required.

2. Concluding remarks, further perspectives

Considering the aims of our project, the following concluding remarks can be stated.

(1) Based on our studies we suggest that in anthropic geomorphological studies the 'intentional' and 'unintentional' term should be used. Reviewing the concerning literature, we concluded that 'anthropic' 'semi-anthropic' as well as 'natural', 'semi-natural', 'artificial' terms would rather be used in description of a certain form than for naming a type of landforms.

(2) A database terraces in the Nagy Hill and some other areas in the Tokaj Foothill Region was compiled. These forms have not been intensively studied by geomorphological point of view. Quantifying the geomorphological activity required for building these objects was attempted.

(3) We reviewed geomorphological importance of the regional municipal waste deposits. Their classification was also made. In our opinion they represent a special anthropic geomorphological group called as 'special transferred urbanogenic forms'.

(4) We made more attempts to quantify anthropic geomorphological processes. Based on results of our and former studies, we suggest to introduce the term 'hemeromorphy' to express the degree of human influence on geomorphosystems (complexes of surface forming processes) independently from their geomorphic process combinations, relief and climate. Similarly, quantification of mining disturbance was also attempted.

(5) During the project we analysed interrelationships of social-economic conditions and human geomorphological activities. Our study in northern part of the East Borsod Coal Basin revealed that there is positive correlation between coal mining activity as well as the built-up area and number of houses of the settlement. It was also revealed that although coal mining activity may have significant short-term effect on population and land use pattern of settlements involved, coal mining itself does not improve long-term sustainable development of the settlements.

(6) Comparative studies of areas characterized by different human activities and geographic conditions suggest that radical social-economic changes may have an impact on land use pattern in different ways. Based on long-term study on changes in land use pattern for different model areas we concluded that land use pattern could be

extremely useful for anthropic geomorphological studies of historic approach. It was also demonstrated that this kind of studies may have landscape planning implications.

(7) Our study was made on microregional level. These studies could be analysed in the context of the social-economic history of Hungary; however, interrelationships of different areas (e.g. geographic, economic, administrative, etc. microregion) could be more understood and interpreted on regional level. For this reason it would be useful to fill geographic ‘gaps’ amongst the studied areas. We intend to continue our further studies by this consideration.

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