Europ. Countrys. · 2 · 2017 · p. 230-244
DOI: 10.1515/euco-2017-0014

European Countryside MENDELU

QUANTITATIVE ASSESSMENT OF LANDSCAPE LOAD CAUSED BY MINING ACTIVITY

Gábor Csüllög, Gergely Horváth, László Tamás,
Mária Szabó, Béla Munkácsy[1]

[1] Eötvös Loránd University, Faculty of Science, Institute of Geography and Earth Sciences, Department of Environmental and Landscape Geography, H-1117 Budapest, Hungary, gcsullog@caesar.elte.hu

Received 20 June 2016; Accepted 11 November 2016

Abstract: In Hungary, not only the aftermath of the extraction in the past nearly 150 years, but also the economic changes taking place in the past two decades have had significant environmental consequences manifested, above all, in the landscape. It is, however, not sufficient to investigate the landscape components separately; it is necessary to explore connections within the landscape. Accordingly, the chief aim of this presentation has been, on the one hand, to work out the method of landscape load index, based on a quantitative database of mining claims and deposits of mining waste, which has revealed their impacts on the landscape as well. On the other hand, we have also aimed at developing the method of the mining load index of certain geographical landscape units. By calculating and analysing the indices, we have intended to build a quantitative database suitable for investigating the impacts of mining activities on the landscape. On the basis of the indices, the impacts and consequences could be ranked, and it was also possible to compare the impacts of different mining claims and waste deposits in three different landscape categories. With the main result of our examination, this will make it possible to investigate concrete problems and landscape conflicts caused by the landscape use of mining or its aftermath in different landscape units with a high load index.

Keywords: mining, mining claims, landscape load, landscape load index, GIS, Hungary

Összefoglaló: A bányavidékek a leromlott (degradált) tájak legklasszikusabb példái közé tartoznak. Nem lehet vitatni, hogy a bányászat a legnagyobb tájterhelő tényezők közé sorolható, a bányászat felhagyása éppen úgy komoly környezeti következményekkel jár, mint maga a kitermelés. Kutatásaink egyik fő célja ezért a bányászat (a bányatelkek, bezárt bányák és bányászati hulladéklerakók) tájra gyakorolt hatását vizsgálni, regionálisan pedig Magyarország egyes tájegységeinek tájterheltségét mérhető formában meghatározni a tájkonfliktusok megoldása és táj revitalizációja érdekében. Ehhez a bányatelkek és bányászati hulladéklerakók mennyiségi adatbázisából kiindulva kidolgoztuk egyrészt a bányatelkek tájra gyakorló hatását kimutató terhelési indexe, másrészt a lehatárolt földrajzi tájak (kistájak) bányászati terheltségének indexe meghatározásának módszerét. Az értékek számítása és elemzése révén létrejövő minőségi adatbázis lehetővé teszi a bányászat által okozott hatások táji keretekben való vizsgálatát és elősegíti a bányászati tevékenység által leginkább befolyásolt tájak, tájtípusok problémáinak értelmezését és kezelését.

Kulcsszavak: bányászat, bányatelkek, tájterhelés, tájterhelési index, GIS, Magyarország

1. Introduction

In the emerging industrial era of the mid-19th century, sectors of economy having a direct impact on the environment, such as mining, energy production, ore processing, ceramics and glass industry and, as a result of the advancement of industrialisation, waste and sewage management, had gained great significance. Mining transforms important landscape elements (rocks, soil, vegetation, water, etc.), creating negative and positive morphological elements. It also changes surface forms, has an impact on water balance, decreases surfaces covered by vegetation and, and at the same time, erects a large number of artificial constructions (Csüllög & Horváth, 2007).

As the occurrence of various natural resources is very often linked to a particular landscape environment, mining activity had become powerful in certain regions, dismantling previous natural and cultural landscape systems. The ore and coal mines (and the regionally attached industries), river regulations, quarries and stone workshops, which satisfy the needs of railway and town constructions, had not merely become decisive but even prevailed over landscape elements by outranking previous cultural landscape components. Neither had lowland landscapes that remained intact, and besides clay mining and processing, gravel mining and sand exploitation also increased significantly. We have to establish the fact, however, that despite their numerous drawbacks, industrial and mining landscape components are just as important parts of the landscape as the natural elements. Without them, cultural landscapes would not be worth speaking about (Horváth & Csüllög, 2012a, 2012b).

Ending industry and mining was only partly beneficial for the environment: the direct harmful effects of active operation had been stopped, but several decades of landscape load, with some exceptions, have not decreased. Consequently, the most serious landscape conflicts are present in these abandoned mining and industrial regions currently (Filip & Cocean, 2012, Tamás et al., 2013). The basic problem of handling these conflicts is that the transformed landscape is a new system, which differs from both the landscape of industrialisation as well as the one existing prior to it. An ad hoc shaping of the landscape as well as its technically successful rehabilitation, reclamation or revitalisation, merely conserves a previous, seemingly favourable condition. It does not, however, solve landscape utilisation problems as they are too complex due to mining activity and its aftermath. Among these problems are, for instance, environmental hazards, such as permanent water, air, pollution, and soil contamination as a result of building mine and waste dumps. Equally, serious problems have been caused by damaging water bases, surfaces caving in, and by disturbing the vegetation. What occurs to be the biggest of all problems is the lack of *function.* This means that abandoning the earlier use of the landscape for industrial and mining purposes, no income producing economic interest has appeared (Harfst & Wirth, 2011). Consequently, what seems to be the most urgent task is to avert environmental hazards as well as to make and carry out plans for landscape use in accordance with new functions (Wirth et al., 2012; Horváth et al., 2012).

Furthermore, the fact is that current economic processes also require a considerable amount of natural resources, which cannot be ignored either. That is to say, the country's economy is in constant need of available resources produced and utilised economically. Extraction, however, should not entail serious consequences that are difficult to handle. A kind of balance must be found between economic interest and the optimum condition of the environment since economy does not only need raw materials and energy sources, but a pleasurable living environment as well (Ianos et al., 2012).

Although, mining affects certain environmental components with greater force than others, its complex impact is initially manifested in relation to the landscape, in the first place. This accounts for the necessity to explore these relations and to analyse landscape conflicts. A coordinated landscape management, therefore, is of great necessity, which has to be effective enough to solve the environmental and landscape problems of the abandoned mines and to decrease the complex environmental load of active mining (extraction, transportation, waste-heap deposition, pollution of water, soil and air, vegetation damages) as well.

Until now, landscape conflicts have remained unsolved. What is worse is that they are not being explored scientifically, partly because there is no national survey or analysis of such landscape problems going on. On the other hand, short- and long-term management plans have yet to be worked out and coordinated, and organisational frameworks need to be built. In order to give a full explanation, as well as proper landscape-protecting solutions to the problems caused by mining, the size of the impact of the past and present mining on the landscape will have to be assessed. An effective approach will be marking out landscape impacts, which then can be put into proper value categories following GIS analyses. As a result, it will be possible to carry out modelling and evaluation suitable for landscape management.

The figures assessed within the landscape frameworks will make it possible to identify types of landscape most heavily affected by mining. The index introduced earlier can be a useful method as it is applicable to small landscape units all over the country, and also shows the size of mining load in the landscape as well.

On the basis of the situation outlined above, the aim of this presentation has been, on the one hand, to work out the method of landscape load index, based on a quantitative database of mining claims and deposits of mining waste, which has revealed their impacts on the landscape. On the other hand, we have also aimed at developing the method of the mining load index of certain geographical landscape units. By calculating and analysing the indices, we have intended to build a high-standard database suitable for investigating the impacts of mining activities on the landscape. On the basis of the indices, the impacts and consequences could be ranked, and it was also possible to compare the impacts of different mining claims and waste deposits in three different landscape categories. As the main result of our examination, this will make it possible to investigate concrete problems and landscape conflicts caused by the landscape use of mining or its aftermath in different landscape units with a high load index (Szabó et al., 2012).

2. Databases

This phase of the research was based mainly on the GIS processing of statistical databases. Consequently, we analysed various economic, environmental and landscape databases connected to mining, on the basis of which we have worked out the index of mining landscape load. This index could be used to draw up basic national-scale maps essential for making comparisons.

2.1 Database of small landscape units

In our study, we chose the landscape unit cadastre of Hungary (Dövényi, 2010) for our landscape database. In the database, 249 polygons make up the cadastre of Hungary's landscape units (Figure 1).

Landscape components appear as unique systems within the delimited landscape frameworks while depending on individual conditions such as height, configuration, soil types, hydrological characteristics, vegetation, etc. They also show a large variety. Therefore, we found it necessary to rank the small landscape units into three categories on the basis of their main characteristics so as to make the study of interactions between mining and landscape simpler.

The first group is the category of lowlands and plain landscape units. Here, we put plains 200 metres below sea level and wider plain-like river valleys between mountains and hills. The second one is the category of hilly landscapes, where we have included individual hills, hills among and on the peripheries of mountains as well as troughs and larger basins between them. The third category is the group of mountainous landscapes with mountains over 500 metres with small basins between them. (To make it simpler, from now on, we will refer to the three groups as 1. plain and valley landscapes; 2. hilly landscapes; 3. mountainous landscapes.) It is important to make this kind of differentiation because these landscape units in the three categories differ not only with respect to their natural character, but to landscape use as well. In consequence, landscape problems and the way they are handled are different as well (Figure 1 and Table 1).

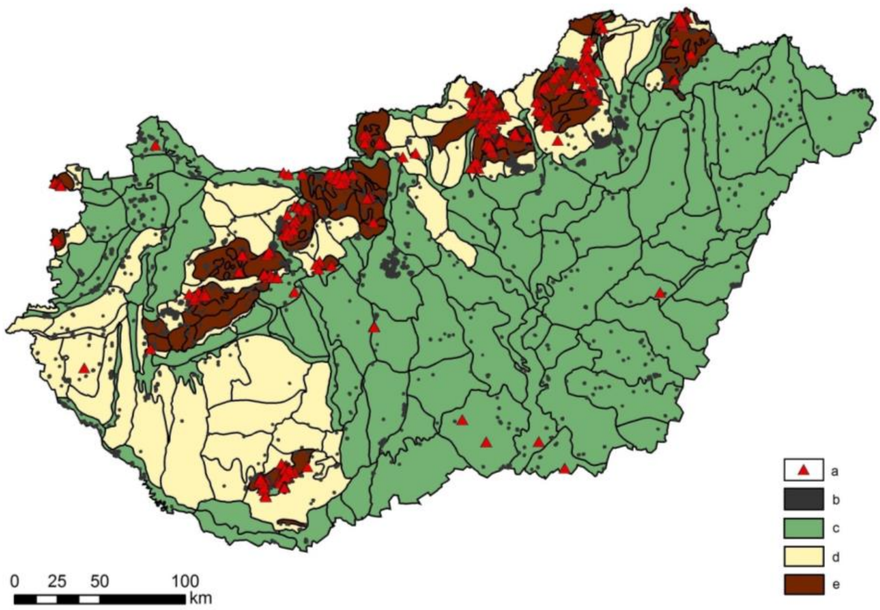

Fig 1. Hungary's mining claims and waste dumps of abandoned mines distributed in the three main landscape categories. Legend: a – waste dumps of abandoned mines; b – deep working and open-cast mining claims; c – plain and valley, d – hilly, e – mountainous landscapes.

Tab 1. The number and distribution of Hungarian landscape units on the basis of the three main landscape categories.

Mountain	Hilly	Plain and valley	Total
68	70	111	249

2.2 Database of mining claims

The first step in determining the mining load was the exact mapping of mines' types. A basic source of data was the recording of mining claims in the database issued by the Hungarian Office of Mining and Geology. They are the current versions of the digital map of licensed mining areas, more precisely, of areas where economic activity including reclamation is still going on. This database is an open source updated quarterly. It contains the most important data on Hungary's mining claims including, for example, the type of mineral resources, forms of cultivation, levels of mining activity, the territorial expansion of mining sites, the underground depth of mineral resources, as well as the ownership of mining sites and their EOV coordinates. All these data are stored in a complex GIS database, so they can be analysed accordingly. In our database, we store 1144 mining claims (Figure 2). We have left out, however, the data of 680 mining claims (hydrocarbon, CO_2, thermal and mineral waters) from our study because they should rather be ranked with the landscape load examination of industrial projects given the difference in their construction, operation and impact on the landscape. The data stored in the database reflect the state of affairs on April 4th, 2014, and contains the coordinates of the corners of the mining claims.

Tab 2. Hungarian mining claims and facilities for handling mining waste in the division of three landscape categories.

	Mining claims	Waste dumps	Total
Mountainous	227	242	469
Hilly	374	157	531
Plain and Valley	703	53	756
Total	1,304	452	1,756

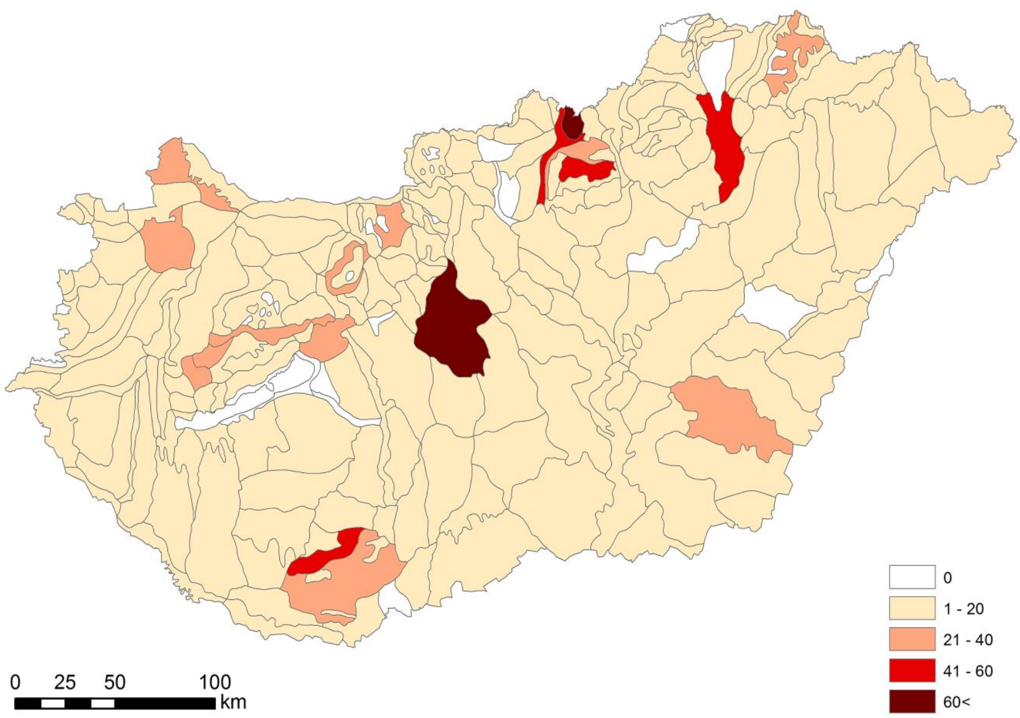

Fig 2. The number of mining claims and waste dumps by landscape units.

2.3 Database of facilities for handling mining waste

In the database issued by the Hungarian Office for Mining and Geology, waste deposits on once active mining sites in Hungary, related to mining or built as a result of mining, can be found. Accordingly, facilities for handling mining waste on abandoned waste dumps mean both the waste dumps of barren rock and the waste deposits of materials used during the mining activity have piled up directly on the mining area. These facilities (altogether 463) have had considerable environmental impacts as they are active sources of environmental conflicts even today.

The register of facilities for handling waste in the abandoned mines was made in 2012, on the basis of the database of April 20th, 2014. It contains also the coordinates of the centre of the facilities (Figure 2 and Table 2).

3. Methods applied

We have worked out the evaluation of the landscape load of landscape units in six steps by applying the methods presented below (Figure 3). Mining activity may appear in various forms in time and space. First of all, the type and form of mining activity had to be specified as well as what kind of activity was taking place on the given plot.

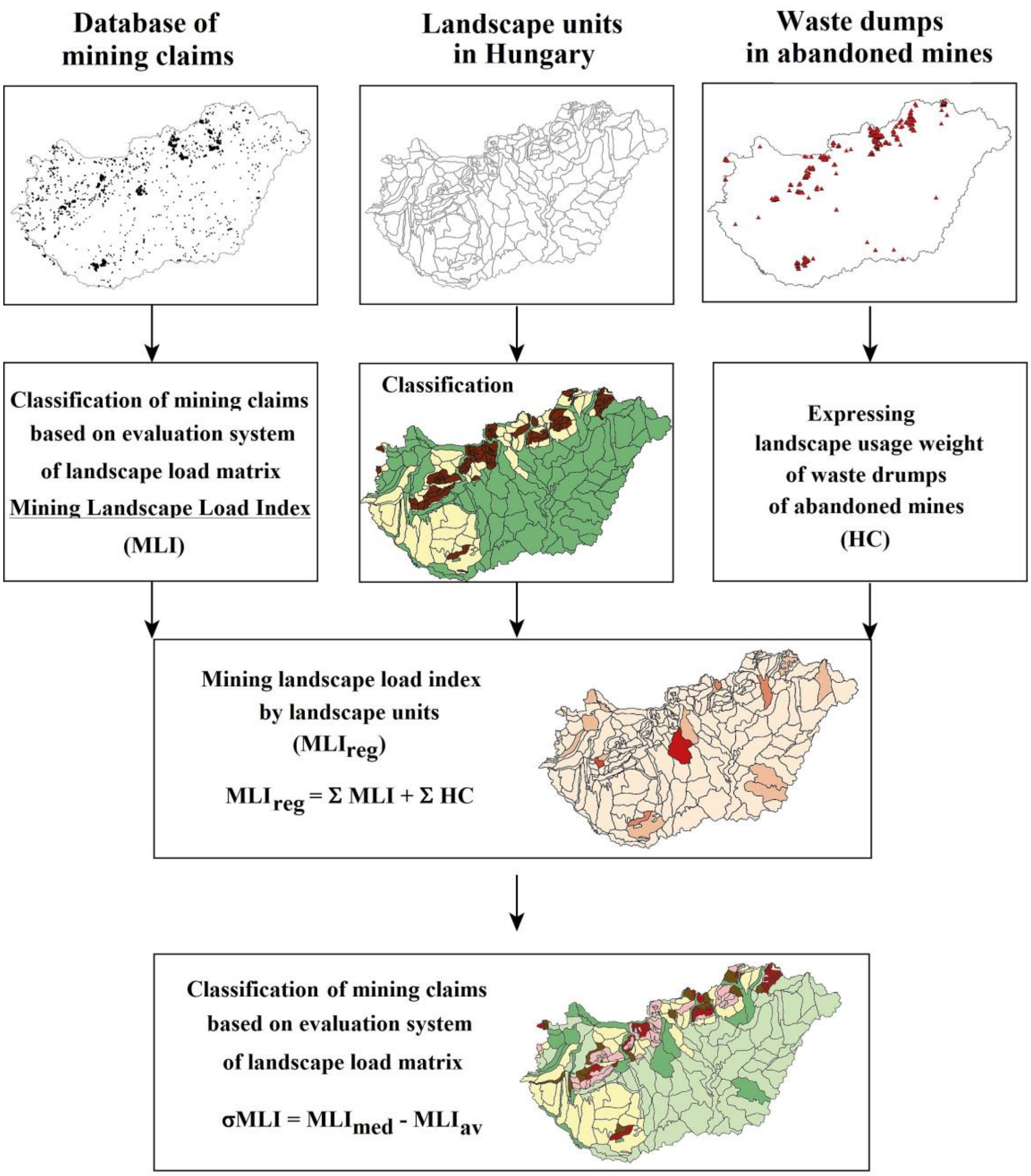

Fig 3. Modelling the landscape load examination of the mining claims.

3.1 Definition of the mining landscape load index

3.1.1 The landscape load index of mining claims

The mining claims were put into different load classes according to their size, type of raw material, method and technology of exploitation, because the more material that had to be moved into larger and larger areas, the bigger the impact it will have on the landscape. It is necessary to emphasise this in an empirical evaluation, which has to be carried out based on functions of different mine types, sizes and operation modes (Tamás, 2012).

In relation to landscapes, surface operations, which make up almost 90% of active mining today without hydrocarbons, have a stronger impact. At the same time, the formerly significant underground exploitation has also had perceptible landscape impacts up to the present day by affecting surface dumps, abandoned facilities and the water system.

The mining claims were divided into 6 groups based on *the type of operation that* has a significant impact on the landscape environment:

1. open-cast coal, lignite and bauxite mining;
2. deep-working coal mining;
3. deep-working ore mining (copper, uranium, manganese etc.);
4. open-cast gravel, sand, clay mining;
5. open-cast rock mining for the building industry (limestone, dolomite, basalt etc.);
6. mostly open-cast mining of other raw materials (peat, kaolin etc.).

In the study, we attempted to work out a method which is adaptable to all mine types and to each of the several thousand mining claims. Therefore, the aspects of the examination had to be simplified and narrowed down as much as possible.

The purpose of the evaluation was to work out a *mining landscape load index*. This index is a relative number without a unit of measurement.

Based on experiences in Hungary, for index calculation, we assigned 0, 1, or 2 points to the 6 above listed types of mines with regard to the *characteristic features and activities* presented in Table 3. Namely, 2 points = indicate typical, 1 point = secondary, 0 point = non-typical features and activities. Of course, the types are merged for the sake of manageability, and the values were determined according to that. These values are not uniform for all types of mining activity, nevertheless, e.g. a landscape fragmentation is mostly more characteristic in case of open-cast coal, bauxite or lignite mines of big extent (therefore the given value is 2); less typical for open-cast mining of other raw materials of smaller extent e.g. in case of peat or kaolin extraction (therefore the given value is 1), and hardly characteristic in case of deep working (therefore the given value is 0).

Tab 3. Distinctive properties of mining claims in the case of individual mine types. See the explanation of the points in the text.

Factors	Types of mines					
	Open-cast coal, lignite and bauxite mining	Deep working coal mining	Open-cast gravel, sand and clay mining	Deep working ore mining	Open-cast rock mining for the building industry	Mainly open-cast mining of other raw materials
Direct environmental hazard of exploitation	1	2	0	1	0	0
Moving of material	2	2	2	1	2	1
Utilisation of energy	2	2	1	0	0	0
Pollution of primary processing	2	2	1	2	1	1
Presence of services	2	2	1	2	1	1
Mine dumps	2	2	1	2	1	1
Presence of heavy metals	1	2	0	2	0	0
Dust pollution	2	1	2	2	1	1
Landscape fragmentation	2	0	2	0	1	1
Impact on landscape	2	1	1	1	1	1
Soil degradation	2	1	2	1	1	1
Ground water level damage	2	0	2	0	0	0
Clearing natural vegetation	2	1	2	1	1	1
Water take-out	1	2	1	2	1	1
Noise	1	0	1	0	1	0
Total	26	20	19	17	12	10

This method of calculation, however, proved insufficient to characterise the mining claims accurately. Thus, in order to create a landscape load index suitable to show the differences with greater accuracy, the mining claims had to be weighted according to their size and activity.

Weights of activity to be analysed included activeness of function in the three categories of working, closed down, and under reclamation, as well as the area of the mining claim in question. Accordingly, the following *activity points* were given to the mining claims:

a) there is active mining – 10 points,

b) mining activity had been stopped – 7 points,

c) mining activity is under reclamation – 2 points.

For *weights depending on the basic area of the mining claim*, we established a classification from 1 to 10, according to area expansion. This can be calculated with the following formula:

$Wt = 10\ (T_b / T_{bmax})$

where

Wt: area weight for the mining claim,

T_b: area of the mining claims (km^2),

T_{bmax}: area of the largest mining claim (km^2).

Finally, the basic points, the activity points and area weight points were added up for each mining claim (Table 4). The numbers received in this way have given the mining landscape load index of the mining claims (MLI).

Tab 4. Summary of calculating the mining landscape load index (MLI).

<table>
<tr><th colspan="2" rowspan="3">Exploited raw material</th><th rowspan="3">Basic points (depending on raw material types)</th><th colspan="4">Weights (activity dependent)</th></tr>
<tr><th colspan="3">on the basis of type mining activity, on mining claims</th><th rowspan="2">on the basis of the area of the mining claim</th></tr>
<tr><th>active</th><th>abandoned</th><th>reclaimed</th></tr>
<tr><td rowspan="6">Raw materials</td><td>coal, lignite (open-cast)</td><td>26</td><td rowspan="6">10</td><td rowspan="6">7</td><td rowspan="6">2</td><td rowspan="6">1 - 10</td></tr>
<tr><td>coal (deep-working)</td><td>20</td></tr>
<tr><td>gravel, clay, sand</td><td>19</td></tr>
<tr><td>ores</td><td>17</td></tr>
<tr><td>rocks for building industry</td><td>12</td></tr>
<tr><td>other raw materials not for building industry</td><td>10</td></tr>
</table>

The relative number of landscape load could have been maximum 50 points on a scale closed from above. The *largest number* was 46 (lignite mines). The fact that the smallest number was 15 indicates that this method is suitable for showing differences.

3.1.2 Definition of the landscape-use weight of waste dumps of abandoned mines

The waste dumps of abandoned mines are closely attached to the mining claims and play a very important part in the life cycles of the various branches of mining. As mentioned above, these dumps are formed by dumping slag, auxiliary materials and waste remaining after the exploitation. They also had to be taken into consideration during the calculation, as despite their point-like appearance, they significantly increased the landscape load of the individual landscape units. We found that their landscape-use weight should be uniformly considered. That is why we ordered a constant value (marked HC) to each mining waste dump, which we defined as 25 points, half of the maximum value of MLI. This is accounted for by the fact that their presence in and impact on the landscape is lasting, though not as powerful as with active mining.

3.2 The definition of the total mining landscape load index of individual landscape units

As we indicated before, it is useful to calculate the weights for certain territorial units to facilitate the comparison of mining weights appearing in the landscape. For this, we took the geographical landscape units into consideration. The index derived from the weights of mining claims and waste dumps of abandoned mines projects and sums up the weight of all mining load on the level of landscape units. Consequently, as the last step of our calculations, in order to define the mining landscape load index per landscape units, we added up the indices derived from mining claims and the waste dumps of abandoned mines according to the following formula:

$MLI_{reg} = \Sigma\ MLI + \Sigma\ HC$,

where

MLI is the mining landscape load index of individual mining claims, and

HC is the above-mentioned constant relating to mining waste dumps.

In the case of mining claims located on the border of 2 or more landscape units, the mining landscape load index will raise the number of points of each landscape unit to the same degree.

3.3 Classification of landscape units according to the weight of mining landscape use

A number without a unit of measurement is, obviously, rather meaningless. It seemed, therefore, worth comparing the mining landscape load indices of landscape units by averaging the above-mentioned three categories, one by one, after we had placed the landscape units into one of them. Subsequently, we examined the deviations from the average and drew conclusions from them.

Firstly, we divided the mining landscape load indices per landscape units (MLI_{reg}) by the area of the given landscape unit, and we got the mining landscape load per square kilometres (MLI_{med}).

Secondly, we summed up the landscape load indices in the 3 main landscape categories (see 1.1.) and, similarly to the earlier method, we calculated the average within the given category for 1 square kilometre (MLI_{av}).

Lastly, we examined how much the individual landscape units differ from the average of their category. In other words, with each landscape unit, we subtracted the mining landscape load per km^2 from the average of its own category, as a result of which we got the deviations from the average:

$\sigma_{MLI} = MLI_{av} - MLI_{med}$

These deviations can have both positive and negative values; we considered the previous ones as above average, while the latter ones as under average, according to their load.

4. Results

4.1 Classification of mining claims according to their landscape load indices in a national division

The definition of the impact of mining on landscape units was based on the landscape load index (MLI) introduced earlier in this study. On the basis of the indices, 5 distinctive groups are showing up, which bear particular geographical characteristics with regard to the certain landscape units.

1. The less loaded mining claims of low anthropogenic impact are characterised by the suspension of, or very low mining activity. This group comprises mining claims receiving less than 20 points.

2. Higher values, 20–25 points were given to quarries spread in most of the country's mountains. These are small mining claims of a couple of hectares, but active mining has been going on in several of them for decades. Roads, mine-heaps and smaller facilities are attached to many of them.

3. Within the medium-load category (26–30 points), our country's large gravel mines (Délegyháza, Nyékládháza, Mura-Dráva region) can be found, where mining activity has had a significant impact on the landscape. Nearly all of the sand, clay and kaolin mines belong to this group. In addition, part of the deep-working coal mines can also be ranked among them. Thus, we can conclude that it is the medium landscape load category that can be found in the largest number in the country.

4. The fourth category contains the group of mining claims with 31–35 landscape load points. This category mainly characterises the medium-height mountainous regions of the country as a result

of the heavy landscape load impacts of coal and bauxite mining. These mining claims differ from the ones in the next category in that most of them are inactive or abandoned mines.

5. The category showing the results of the harshest anthropogenic intervention results (over 35 points) includes the largest and best-known Hungarian mines. Two large lignite mines and the largest bauxite mines belong here, several of which are still active. It can be seen that in these areas mining is not a unique phenomenon, as not only individual mines received high landscape load values. Loaded and transformed surfaces appear here in groups as well, therefore, they can be legitimately called as mining regions or mining landscapes.

4.2 Introduction of landscape units on the basis of the totalled load index (MLI_{reg}) of mining claims

The totalled landscape load index of the landscape units (MLI_{reg}) reflect significant differences in the main mining processes in Hungary, especially in the peculiarities of the situation following the change of the political system. The totalled values of the landscape load indices of the mining claims and of the waste dumps of abandoned mines can be seen in Figure 4, broken down according to landscape units.

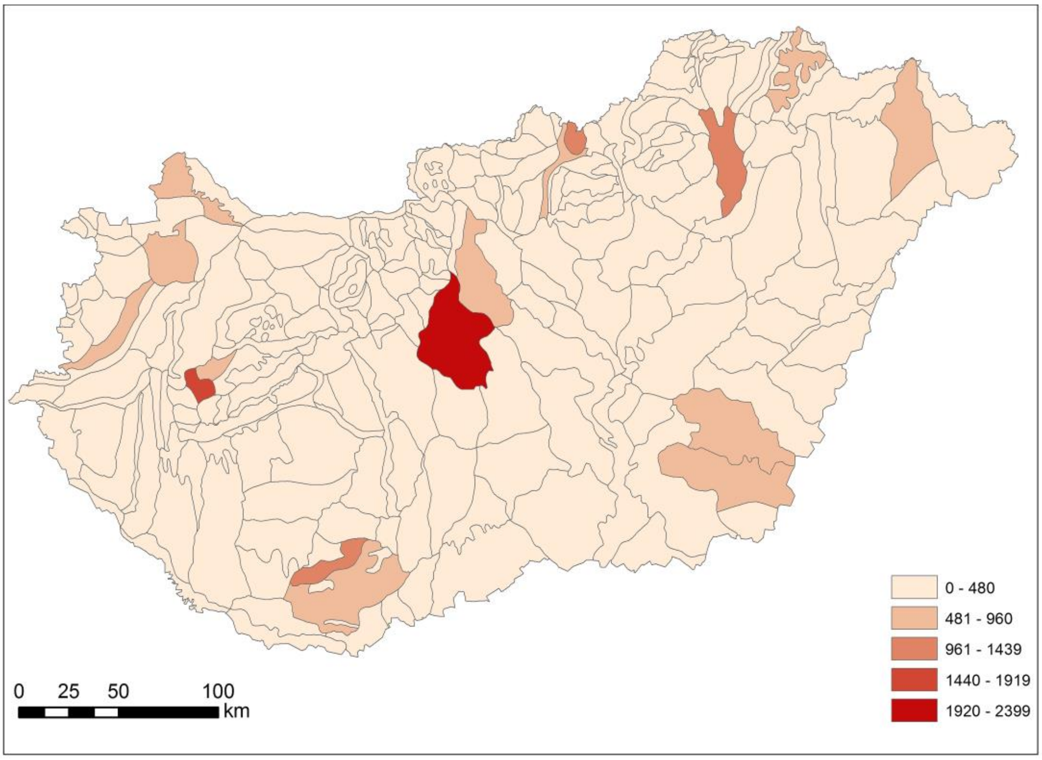

Fig 4. Array of mining claims on the basis of landscape load indices.

The received values of indices and their geographical relations formed according to the initial hypotheses of our research. Although, the totalled mining landscape load of the landscape units well represented the mining regions of Hungary, landscapes of a traditionally plain character and large size were more likely to receive higher totalled points. That is why it was necessary to weight the received results by the size of the area of the landscapes. The results received in this way could already highlight significant landscapes according to their values, and made an objective comparison possible. They could, however, not show differences deriving from the divergent characters of landscapes. Consequently, it was only an examination done on the basis of the categories that could show values worth highlighting and comparing.

4.3 Classification of landscape units of the three landscape categories according to the weight of mining landscape use

The occurrence of mined raw materials and applied mining technologies are closely connected to basic geological and surface morphological characteristics (Tlapáková et al., 2013).

The impacts of exploitation result in different sized loads in the different types of landscapes because of the different proportions of sensitive landscape components. Therefore, in order to avoid distortions by differences in mining, we equalised these distortions by calculating the weighted average of the three main landscape categories (Table 5).

Tab 5. The number of landscape units below and above the weighted average.

Categories	Number of landscapes	Number of mining claims and mine waste dumps		Average value	Landscapes below average		Landscapes above average	
		by piece	%		by piece	%	by piece	%
Mountainous	68	469	27	1.77	45	66	23	34
Hilly	70	531	30	0.91	53	76	17	24
Plain and valley	111	756	43	0.50	81	73	30	27
Total	249	1,756	100	0.97	179	72	70	28

On this basis, the most affected landscape units with above-average values could be highlighted. That is to say, landscape units where the development of conflicts was most active could be identified on the basis of these values.

Table 5 shows that the measure of mining impacts on the landscape, that is, the landscape load of mining is in close connection not with the sheer number of mining claims and mining waste dumps, but with the landscape load values of mining claims. The average values of the three main categories reflect the beforehand expected differences concerning the orders, however; and it is essential by numerical and for elaboration adaptable data. Therefore, beyond determining the average values, it is also important to highlight the landscapes, which have values above average, because it represents further considerable and interesting correspondence. For example, 28% of all landscape units are above the national average, indicating a very high territorial concentration of mining impacts. This concentration is also demonstrated in the difference in landscape categories: the above-average proportion of mountainous landscapes is the highest, and their average load value is twice as high as that of the hilly ones (and of the national average, for that matter), and three times higher than the values of plains.

The differences within the landscape categories indicate important connections. Table 6 shows that, in the case of landscapes with a high load value, there are significant above-average differences in all 3 categories. These differences are the biggest in the category of mountainous regions showing both the highest load values (Medves region) and the biggest above-average difference. The fact that not every landscape unit with a high load value and above-average difference can be found in this category and that landscapes loaded above the national average can be found in all 3 categories, shows that mining landscape use can be significant not only in the traditionally mountainous regions, but also in the hilly, and plain and valley, landscape units as well. Furthermore, in the case of certain hilly, even plain and valley landscapes, there are significant above-average differences. This indicates that there are also significantly loaded landscape units in these categories, which require an appropriate treatment of landscape load caused by mining (Figure 5). Moreover, numerical values of Table 6 draw attention to the fact that although the average values of three main categories are significantly different, however, within the categories, such values can also be found, which are characteristic of another category. E. g. the totalled and weighted mining landscape load value of the Zagyva Valley (which belongs to the 'Plain and Valley' category) is bigger than that of the Fertő Region which has the third highest value within the 'Hilly' category. It indicates that the concentration of the mining activity is linked up not only with the general characteristics of the landscape types, but also individual factors play a role. Therefore, working out further methods in landscape load investigations, also this correspondence also has to be taken into consideration.

Tab 6. Landscape units most divergent from landscape categories above the weighted average.

Categories	Landscape units	Number of mining claims		Number of closed mines	Load value of closed mines	Total sum of mining landscape load value	Totalled and weighted mining landscape load value (/km^2)	Deviation from the average value of landscape type (/km^2)
Mountainous average 1.77	Small basins in the Börzsöny Mts.	0	0	3	69	69	7.19	5.43
	Parád–Recsk Basin	6	278	13	299	577	9.56	7.80
	Medves Region	30	1,163	39	897	2,060	15.85	14.10
Hilly average 0.91	Fertő Region	6	285	0	0	285	4.44	3.52
	Foot of the Bakony Mts. at Devecser	17	896	8	184	1,080	7.50	6.58
	Sümeg–Tapolca Ridge	14	1,551	0	0	1,551	10.11	9.19
Plain and valley average 0.50	Mura Left-bank Plain	15	435	0	0	435	3.03	2.54
	Pécs Plain	3	115	5	115	230	4.01	3.52
	Zagyva Valley	22	689	23	529	1,218	6.31	5.82

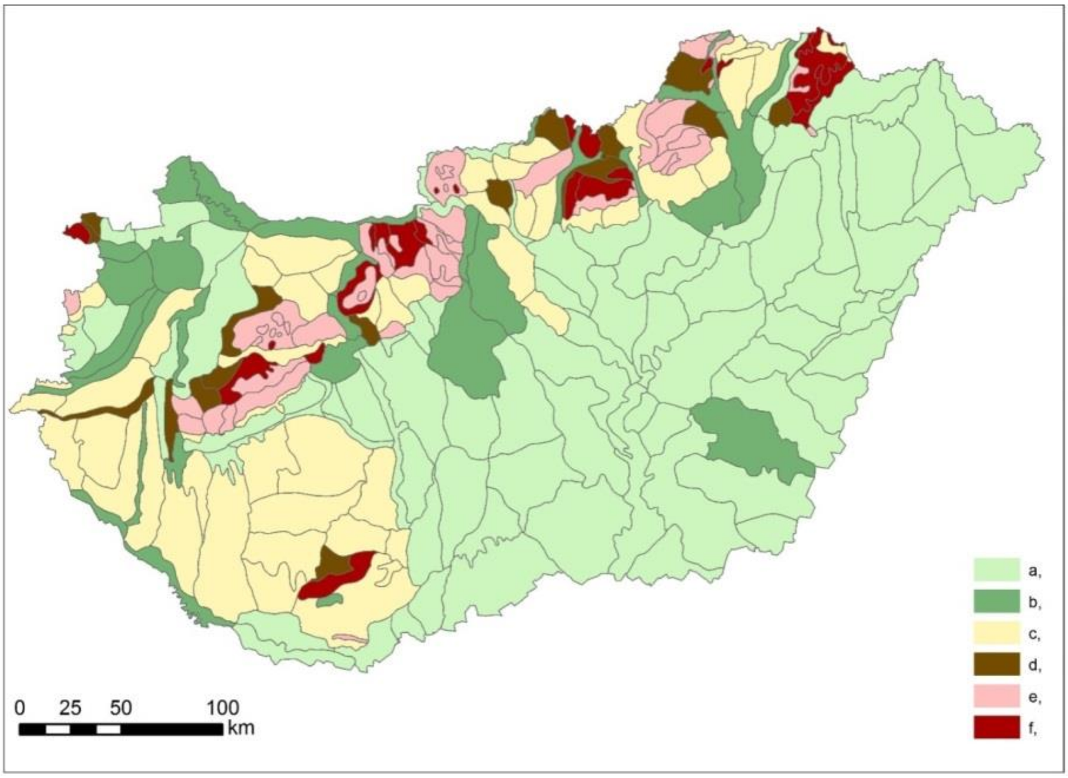

Fig 5. Landscape units' deviations from average values of weighted mining landscape load. Legend: a – plain and valley below average, b – plain and valley above average, c – hilly below average, d – hilly above average, e – mountainous below average, f – mountainous above average

The impacts and consequences can be ranked according to the values of loading and load established by our new method, and the impacts of mining claims and waste facilities will become comparable in the different landscape categories as well. In addition, this ranking highlights the most affected landscape units both nationwide and by categories. As a result, concrete problems and landscape-use conflicts caused by mining or its aftermath on heavily loaded landscape units in the different categories can be examined.

5. Conclusion

The utilisation of the abandoned mining regions and an environment-friendly realisation of the present mining activities are important tasks not only because of the serious environmental and economic problems, but also because a degraded landscape with its unattractive image affects everyday life as well. It is very important to change this image in order to achieve a more positive view of mining and a successful reclamation of the landscape. The first step, therefore, has been to provide the country with an appropriate methodology of survey, database, and objective evaluation. These can serve as a basis for further well thought-out plans for individual areas, which also take the involvement of the landscape into consideration, whether they are new mines, reclamations or reconstructions of the environment. An objective typifier of landscapes and their specific conflicts is still a forthcoming task of geography. Fulfilling this can be helped by typifying and quantifying loads derived from anthropogenic sources, and it may induce to solving practical problems of a scientific analysis of the landscape as well.

Here is a summary of the results of examinations made by applying the above-discussed methods:

- creation of a qualitative database next to the quantitative one;

- summary of the various characteristics of mining claims as value;

- quantifying the load differences of mining claims and representing them by GIS;

- defining the mining landscape use load of landscapes as value;

- demonstrating the load differences of landscapes within a spatial context;

- demonstrating deviations of prevailing landscape categories;

- demonstrating extreme load values within the prevailing landscape categories to identify landscapes with extreme conflicts as value.

In conclusion, it should be emphasised that the mining landscape index, the GIS database and the analyses based on it, can be used to carry out researches into the environment and regional development as well as into a more efficient planning of mining and procedures for handling conflicts.

Acknowledgements

This work was supported by the Hungarian Scientific Research Fund (OTKA K112477).

Academic References

[1] Csüllög, G. & Horváth, G. (2007). Landscape changes at a former industrial area: problems and possibilities. In Kallabova, E., Frantal, B. & Klusácek, P. (eds.): *Regions, localities and landscapes* [CD]. Ostrava: Institute of Geonics, Academy of Sciences of the Czech Republic.

[2] Dövényi, Z., ed. (2010). *Magyarország kistájainak katasztere*. Budapest: Hungarian Academy of Sciences, Geographical Research Institute.

[3] Filip, S. & Cocean, P. (2012). Urban industrial brownfields: constraints and opportunities in Romania. *Carpathian Journal of Earth and Environmental Sciences* 7(4), 155–164.

[4] Harfst, J. & Wirth, P. (2011). Structural change in former mining regions: problems, potentials and capacities in multi-level-governance systems. *Procedia – Social and Behavioral Sciences* 14, 167–176. DOI: 10.1016/j.sbspro.2011.03.033.

[5] Horváth, G. & Csüllög, G. (2012a). The role of ecotourism and geoheritage in the spatial development of former mining regions (pp. 226–240). In Wirth, P., Černič Mali, B. & Fischer, W., eds., *Post-mining regions in Central Europe – problems, potentials, possibilities*. München: Oekom.

[6] Horváth, G. & Csüllög, G. (2012b). Salgótarján (Hungary) – The rise and fall of a mining and industrial region (pp. 40–52). In Wirth, P., Černič Mali, B. & Fischer, W., eds., *Post-mining regions in Central Europe – problems, potentials, possibilities*. München: Oekom.

[7] Horváth, G., Csüllög, G. & Karancsi, Z. (2012). Mines as geosites and objectives of geotourism in Hungary. *Geologia dell'Ambiente*. Suppl. 3, 141–142.

[8] Ianos, I., Sirodoev, I. & Pascariu, G. 2012. Land-use conflicts and environmental policies in two post-socialist urban agglomerations: Bucharest and Chişinău. *Carpathian Journal of Earth and Environmental Sciences* 7(4), 125–136.

[9] Szabó, Sz., Csorba, P. & Szilassi, P. (2012). Tools for landscape ecological planning – scale and aggregation sensitivity of the contagion type landscape metric indices. *Carpathian Journal of Earth and Environmental Sciences* 7(3), 127–136.

[10] Tamás, L. 2012. Az ipar által okozott tájhasználati konfliktusok és az ipari tájterhelés bemutatása térinformatikai módszerekkel. In Lóki, J., ed., *Az elmélet és gyakorlat találkozása a térinformatikában III* (pp. 405–413). Debreceni Egyetemi Kiadó.

[11] Tamás, L., Csüllög, G. & Horváth, G. (2013). Ipari tájak degradációs folyamatainak problémái. In Konkoly-Gyuró, É., Tirászi, Á. & Nagy, G. M., eds., *Tájtudomány – tájtervezés* (pp. 108–114). Sopron: Nyugat-magyarországi Egyetem.

[12] Tlapáková, L., Stejskalová, D., Karásek, P. & Podhrázká, J. (2013). Landscape metrics as a tool for evaluation landscape structure – Case Study Hustopeče. *European Countryside* 5(1), 52–70. DOI: 10.2478/euco-2013-0004.

[13] Wirth, P., Černič Mali, B. & Fischer, W. (2012). Problems and potentials of post-mining regions (pp. 14–30). In Wirth, P., Černič Mali, B. & Fischer, W., eds., *Post-mining regions in Central Europe – problems, potentials, possibilities*. München: Oekom.