The role of mining ponds in the landscape character

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1. Abstract

Landscape character has played an important role in landscape analysis plans of landscape architecture works for decades. Mining ponds – depending on their size – are prominent landscape features both locally and regionally, which define and influence the landscape and landscape character, and often enrich it. The aim of this research is to analyze the international and Hungarian landscape character methodologies to reveal how they deal with the presence of mining ponds, and to analyze the role of mining ponds in landscape character based on the Hungarian landscape character methodology. During this research, a comparison of mining ponds and landscape character type areas was carried out for the whole territory of Hungary, both in terms of the area and the number of mining ponds, using GIS and statistical methods.

A review of international landscape character methodologies showed that the role of mining ponds in shaping landscape character is not found in any of the analyzed methodologies. Landscape character methodologies consider both the mined areas and the presence of water surfaces as indicators of landscape character, but do not distinguish between natural and artificial ponds within water surfaces, nor between water-filled mining ponds within mined areas, therefore do not specifically address mining ponds. In the Hungarian landscape character methodology, mining ponds are mentioned at the level of landscape elements or landscape mosaic units, but at an upper level of the landscape character units (landscape character sub-type, landscape character type, landscape character main type, landscape character area) mining ponds are not mentioned.

This article reveals which landscape character type areas contain the largest number and the largest extent of mining ponds. The so-called 'Water-dominated mosaic plain landscape' and the 'Pond landscape' landscape character-type areas abound in the presence of mining ponds. 14.5% of the 'Water-dominated mosaic plain landscape' landscape character type areas are covered by mining ponds (mostly gravel mines). In these areas, the role of mining activity and the role of mining ponds in shaping the landscape and determining the landscape character is particularly significant. The analysis of the surface area ratios of mining ponds (in hectares) revealed that 67% of the total area of mining ponds is located within or intersects a water-dominated landscape character type area, i.e. the ’Watery landscape’ main type. The majority of these are just a few (in number of pieces) but large within size (over 400 hectares) mining pond systems in Hungary. This result supports the dominant role of large mining pond systems in the landscape character. However, the analysis of the quantity of mining ponds shows that 83% of the total number of mining ponds – a large number of small (in size), single mining ponds – is located in such landscape character type areas which are not influenced by water.

We have analyzed the role of mining ponds in the hierarchy of landscape character areas, depending on their size, and the relationship between average mining pond size and landscape character type. The results show that although the presence of small mining ponds does not affect the landscape

character type classification, the presence of mining ponds and pond systems larger than 10 hectares affects the landscape character type of a given area. Thus, most of the mining pond systems from gravel and peat pits in Hungary have been classified within water-dominated landscape character types based on the landscape character classification.

2. Introduction

The modified surfaces resulting from opencast mining have been present in the landscape for thousands of years, shaping its character. In Hungary, the proportion of surfaces affected by mining activity is almost 6%, including mining ponds and mining pond systems. There is no up-to-date, official inventory of mining ponds in Hungary. About 1.8% (168,500 hectares) of the country's area is covered by standing water, from which 75% (126,370 hectares) is an artificial lake (dam storage or ring dike reservoirs and mining ponds). (VGT3 2021) The register kept by the mining authority only contains data on mines abandoned since 1961, so many mining ponds from previously abandoned mines are not included in the database. The hydrological databases do not include the raw materials of the mines or those wet mining pits that have been reeded and transformed into marshes over time and provide quite different data on the number and extent of standing waters. (Módosné, Hubayné, Varga, 2019) Therefore, we had to carry out a mining pond inventory to establish the basis for our research.

The proportion of mining ponds' area in relation to the total area of the country is nearly 0.2%. 78% of open water surface mining ponds are smaller than 5 hectares and only 1.5% exceeds 50 hectares in size. (Módosné, Hubayné, Varga, 2019)

3. Background and Literature Review

Mining ponds – depending on their size – are prominent landscape features both locally and regionally, which define and influence the landscape and landscape character, and often enrich it. (**Picture 1., 2.**) Although previous literatures – such as studies, publications (Módosné, Boromisza, 2012), diploma theses, doctoral dissertations (Hubayné, 2005) prepared by the predecessors of the Institute of Landscape Architecture, Urban Planning and Green Art of the Hungarian University of Agriculture and Life Sciences – analyzed certain mining ponds and mining pond systems and their role within landscape character, the national overview has not been published so far in Hungary specifically on the influence of mining ponds on landscape character. The topicality of this analysis is given by the advanced stage of landscape character research work in Hungary.

The Hungarian landscape character methodology distinguishes 5 landscape character main types and 49 landscape character types. Water surfaces and areas with water influence which have a landscape character-shaping role are classified in the main type "Watery landscape". Those parts of the country where the presence of water surfaces of ponds is dominant or significant, are classified as a separate landscape character type, the so-called "Pond landscape". Mosaic landscape character types formed by landscape mosaic units with double surface cover dominance, as well as "Diverse" landscape character types with three or more surface cover types, also include landscape character types influenced by ponds. The Hungarian landscape character research mentions mining ponds as landscape elements, and mining ponds surrounded by resort areas as an example of landscape mosaic units, but mining ponds are not mentioned at a higher level of the landscape character hierarchy (landscape character sub-type, landscape character type, landscape character

main type, landscape character area). (Konkoly-Gyuró, 2021 (1))

International landscape character research works and methodologies define mining sites and water surfaces separately in the case of mine ponds and mining pond systems. Several methodologies (e.g. Belgian, Spanish, Hungarian) analyze mines and deposit areas as indicators of land cover (based on Corine or other databases) (Wascher 2005, Otero 2007). However, these predominantly mean 'dry' mines. Water surfaces also appear as indicators of land cover in these research works, likewise based on Corine. These do not distinguish – in terms of landscape character – between natural and artificial lakes. Thus, the role of mining ponds in shaping landscape character is not defined by any of the methods, and they do not appear as a specific indicator in the GIS studies. Among the identified landscape character types and sub-types, only areas influenced by mining activity can be found, but mining ponds do not appear as an independent indicator in any of the methodologies. In the case of Hungarian landscape character research, the situation is similar: mines and ponds are listed separately in the national landscape character classification.

4. Method and Data

The aim of our research is to create a national situation analysis using GIS methods for the data on the quantity (number of pieces) and surface area (hectare) of mining ponds. We focus on the following questions:

- In which landscape character main type and landscape character type areas occur mining ponds with the greatest number and extent?
- Is the size of mining ponds and mining pond systems related to the landscape character type classification?
- What is the proportion of mining ponds within water-dominated, water-influenced and non-water-bound landscape character types?
- Does the location of mining ponds and mining pond systems within the landscape character type areas reflect the key role of mining ponds in the landscape character?

During this research, we compared mining ponds and landscape character type areas for the whole territory of Hungary using GIS – with ArcGis 10.4 software – and statistical methods. The analysis covers both the quantity (number of pieces) and the surface area (hectare) of the mining ponds. The analysis focuses on the mining ponds and mining pond systems formed in the last 50 years (between 1961 and 2022) and water-influenced areas (henceforth these will be parts of the mining ponds) formed due to mining activity. The databases used for the GIS analyses are the following:

- The databases of the Mining and Geological Survey of Hungary (MBFSZ) on abandoned mines and current mining sites include their location, surface extent, status (functioning or abandoned/closed), and the type of extracted raw materials. This database does not include information on the water surface. (MBFSz data, 2019, 2022)
- The National Ecosystem Mapping and Assessment of Hungary, Basin Map (henceforth NÖSZTÉP) (Web ref. 1), was established as a result in the framework of the research project KEHOP-4.3.0-15-2016-00001
- Corine Land Cover (henceforth CLC) map (Web ref. 2)

- OpenStreetMap (henceforth OSM) freely available vector files (Web ref. 3)
- Map files of landscape character areas and landscape character type areas and descriptions for the landscape character type areas created in the framework of the landscape character research (Konkoly-Gyuró, 2021)
- Databases were collected during our previous researches on mining ponds.

Our results are based on the analysis, comparison, and evaluation of the mentioned GIS and map databases. As a first step, in order to determine the appropriate database, we compared the layers of the NÖSZTÉP base map, the CLC map, and the OSM containing water surfaces and water-influenced areas. As a result of the comparison, the OSM database was found to be the most suitable and up-to-date for the analysis. As the second step, we intersected the area of closed or abandoned mining sites with the OSM database containing water surfaces and water-influenced areas. In this way, we selected the mining ponds formed during the analyzed period. According to our hypothesis, in terms of the landscape character mining pond systems have a determining importance, therefore we aggregated mining ponds within 500 m of each other and defined them as mining pond systems in the analysis. As a next step in the GIS analysis, the selected mining ponds were compared with the maps of landscape character main type and landscape character type areas. Dominance analysis was used to represent the spatial pattern of the mining ponds. In this way, the resulting figure shows the priority areas of mining ponds and wetlands in Hungary (**Figure 7**). **Figure 1** shows the most important methodological steps of our research.

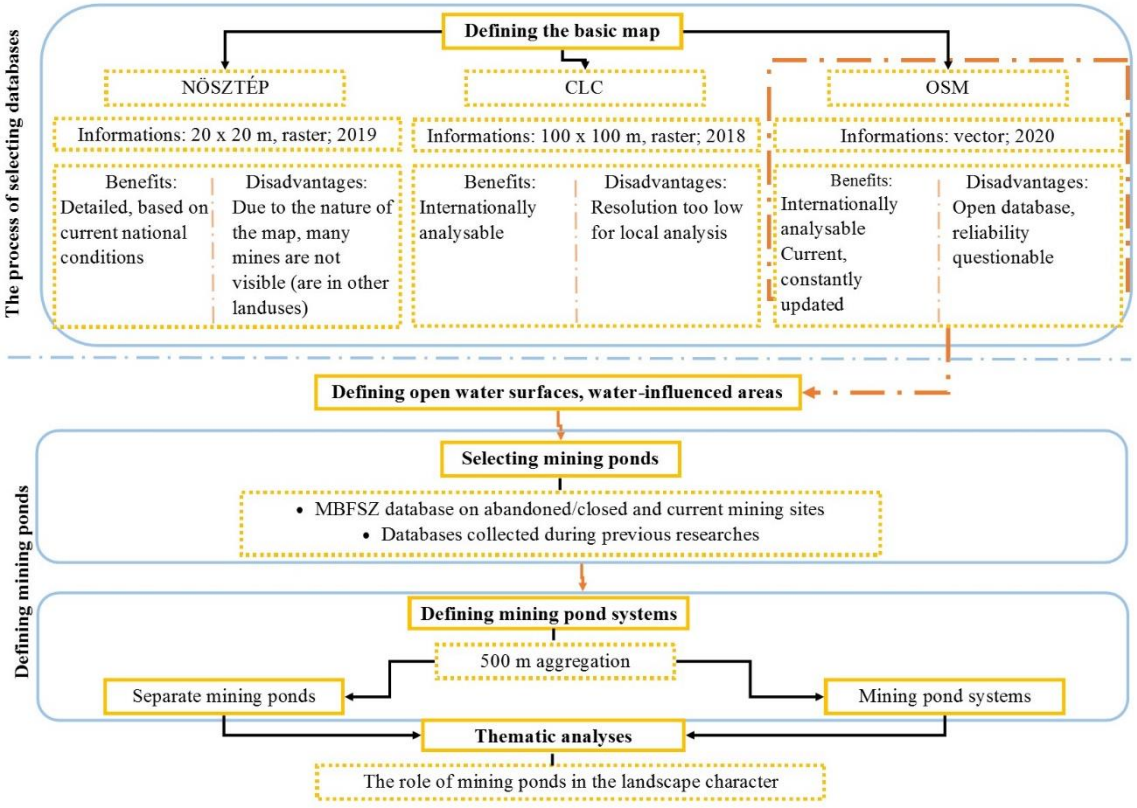

Figure 1. Methodology of the research (own edited figure)

5. Results

The proportion of mining ponds' area in the landscape character main types

In the research, we analyzed the spatial distribution of mining ponds and mining pond systems within the 5 landscape character main types. In proportion to the total area of mining ponds, 67% of the surface extent of mining ponds can be found within the "Watery landscape" landscape character main type, while 13-13% of them are found within "Agricultural landscape" and "Diverse landscape" landscape character main type. Mining ponds are less common (6% and 1% respectively) in the landscape character main types named as "Urban and industrial landscape" and "Woodland landscape" (**Figure 2**).

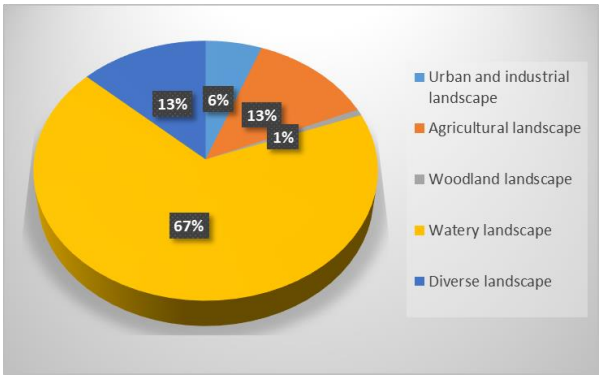

Figure 2. Distribution of the surface extent of mining ponds within landscape character main types in proportion to the total area of mining ponds (own edited figure)

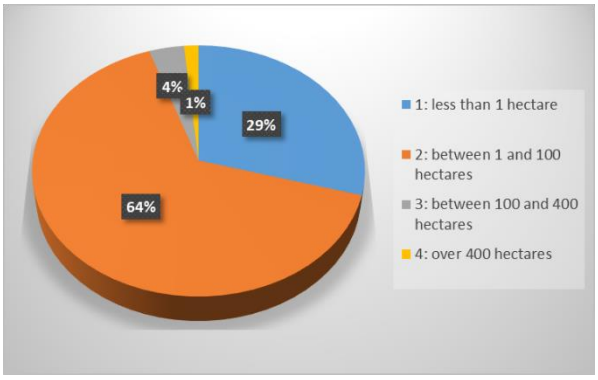

Figure 3. Distribution of mining ponds by size categories (own edited figure)

Distribution of the quantity of mining ponds (number is pieces) and their spatial distribution by landscape character types

In the research, we focused on detecting the spatial distribution of the mining ponds within the 49 landscape character types and identifying the areas where the largest quantity of mining ponds occur. In proportion to their total area, 40.4% of the mining ponds' and mining pond systems' area occurs within the so-called "Water-dominated mosaic plain landscape (431)" landscape character type, while 25.4% occurs within "Pond landscape (421)" landscape character type. In addition to these, there is a higher proportion of mining ponds within "Flatlands with diverse land cover" (10.0%) and "Plough-dominated mosaic flatlands" (9.3%) landscape character types. It is noteworthy that none of these is a water-dominated landscape character type. In the landscapes dominated by rivers ("Landscapes dominated by rivers with diverse land cover and floodplain settlements"), there is also a surprisingly high proportion of mining ponds (8.2%) (e.g. former peat mines in the Marcal valley, gravel mines in the Dráva valley) (**Figure 4**). Slightly different proportions of the distribution of the quantity of mining ponds by landscape character types in relation to the total quantity of mining ponds are shown, as the mining pond systems were defined as a coherent unit after aggregation (**Figure 4**).

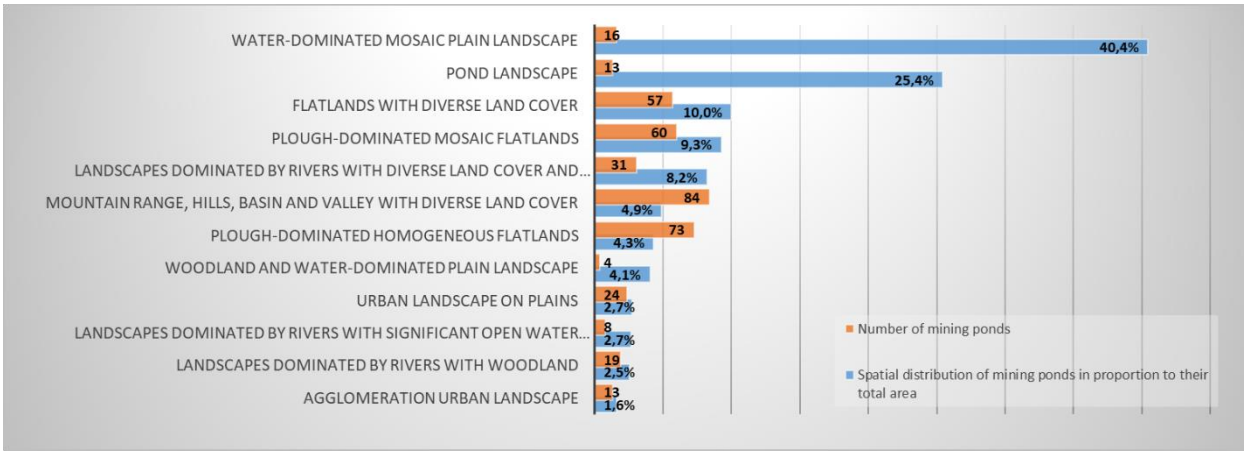

Figure 4. Distribution of the quantity of mining ponds (number in pieces) and their spatial distribution by landscape character types in proportion to the total area of mining ponds (area share of 1% and above; and number of 3 or more) (*Note: There are some mining ponds that intersect more than one landscape character type, that's why the percentages add up to more than 100%.) (own edited figure)

Spatial distribution of mining ponds by landscape character types according to the degree of their water influence

Mining sites are classified into three categories depending on whether they intersect water-dominated, water-influenced, or water-independent (non-water-bound) landscape character areas. Landscape character types classified by the landscape character research as "Watery landscape" were categorized as water-dominant. Mosaic or diverse landscape character types that do not belong to the main category 'Watery landscape' but have the terms water, pond, river in their name were considered as water-influenced. Landscape character types that cannot be classified in the previous two categories were defined as non-water-bound in the analysis. (**Figure 7**)

Figure 5 summarizes the spatial distribution of the mining ponds according to the degree of water influence of each landscape character type. The proportion of the extent of mining ponds or mining pond systems that are located within or intersected a water-dominant landscape character type area is 67% in proportion to the total area of mining ponds. This result is due to the role of mining pond systems in shaping landscape character. Only 1% of the spatial distribution of mining ponds located within water-influenced landscape character types. Nearly a third of the extent of the mining ponds is defined as a water-independent landscape character type.

In terms of the quantity of mining ponds (number of pieces), however, only one sixth of the number of mining ponds or mining ponds aggregated into pond systems is located within water-dominated areas. 83% of the total quantity of mining ponds (number of pieces) – many of them have a small surface – is located within water-independent landscape character types (**Figure 6**).

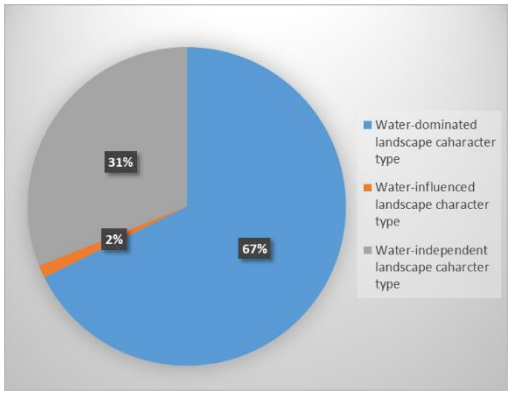

Figure 5. Spatial distribution of mining ponds by landscape character types according to the degree of their water influence (calculated with aggregated pond areas) (own edited figure)

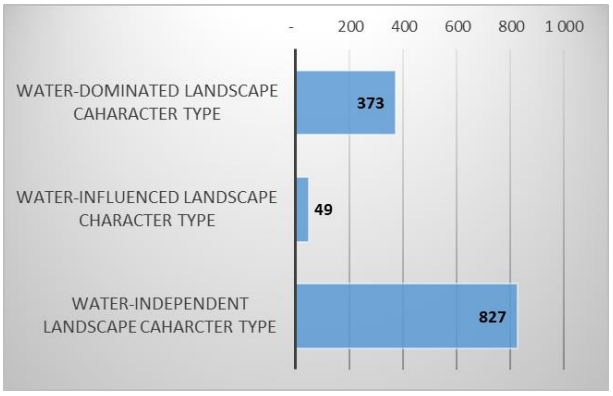

Figure 6. Distribution of the quantity of mining ponds and mining pond systems by landscape character types in proportion to the total quantity of mining ponds (number of pieces) (own edited figure)

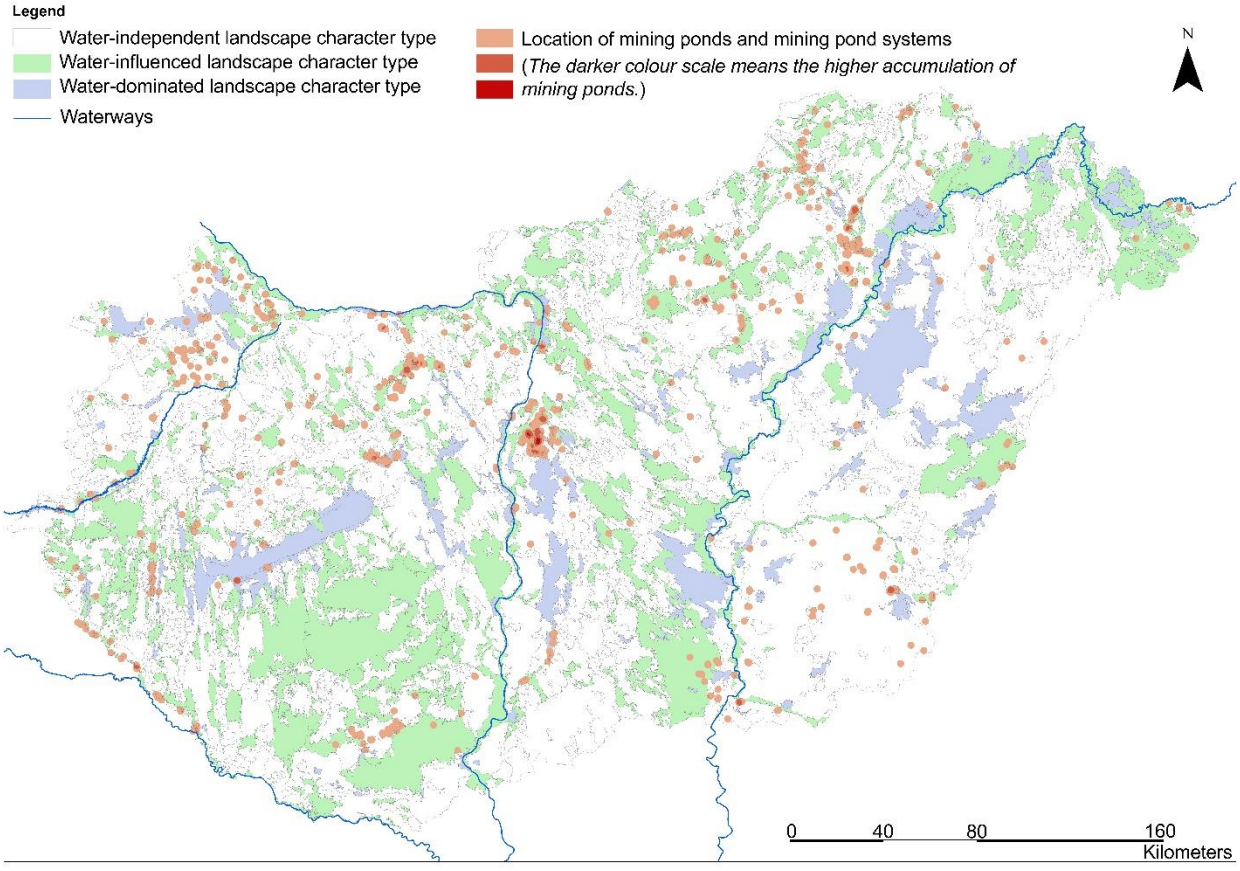

Figure 7. Location of mining ponds within water-dominated and water-influenced landscape character type areas (own edited figure)

The role of mining ponds according to their size in the hierarchy of landscape character units

We have analyzed the role of mining ponds in the hierarchy of landscape elements and landscape character units, depending on their size. (**Figure 3**) Mining ponds below 1 hectare are classified as landscape features in the Hungarian landscape character methodology (Konkoly-Gyuró, 2021). 15% of the mining ponds in Hungary falls into this size category, with a total area of 53 hectares. Mining ponds between 1 hectare and 100 hectares are treated as landscape mosaic units in the Hungarian landscape character methodology. This size category includes 65% of the mining ponds with a total area of 4929 hectares. According to our analyses, areas with the same character between 100 hectares and 400 hectares constitute landscape character sub-types. There are 21 mining pond systems (7% of the mining ponds) of this size category in Hungary with a total of 3145 hectares. Areas of the same character larger than 400 hectares already play a role in delimiting landscape character main types. There are 7 mining pond systems above 400 hectares within this size category. These contain only 13% of the mining ponds, but their surface area represents 44% of the total area of the mining ponds (**Table 1**).

Table 1. Mining pond systems above 400 hectares

Location	Quantity of mining ponds (number of pieces)	Total area of mining pond system (hectares)	Landscape character type codes	Extracted raw material
Nyékládháza	5	542.6	421	gravel, clay
Délegyháza (Picture 2)	68	675.5	421	gravel, sand
Kiskunlacháza	37	843.3	421	gravel, sand
Vindornya valley	4	488.8	431	peat
Red-marsh	11	1186.1	431	peat
Nádasdladány, Várpalota	28	1740.9	431	brown coal, peat
Csorna	8	447.9	432	gravel
*Note to landscape character type codes 421: 'Pond landscape'; 431: 'Water-dominated mosaic plain landscape'; 432: 'Woodland and water-dominated plain landscape'				

Picture 1. A 12 km-long chain of peat mining pond system in the Szévíz valley (Zala county) (Web ref. 4)

Picture 2. The 675.5 hectares gravel mining pond system located in the east of Délegyháza (Pest county) (Web ref. 4)

Relations between mining ponds' size and the landscape character types

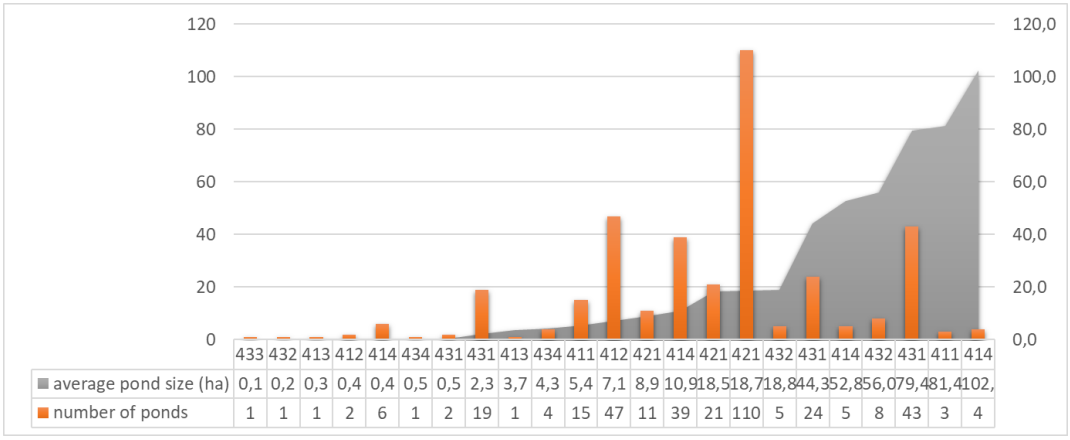

Figure 8. Spatial and size distribution of mining ponds within water-dominated landscape character types (own edited figure)

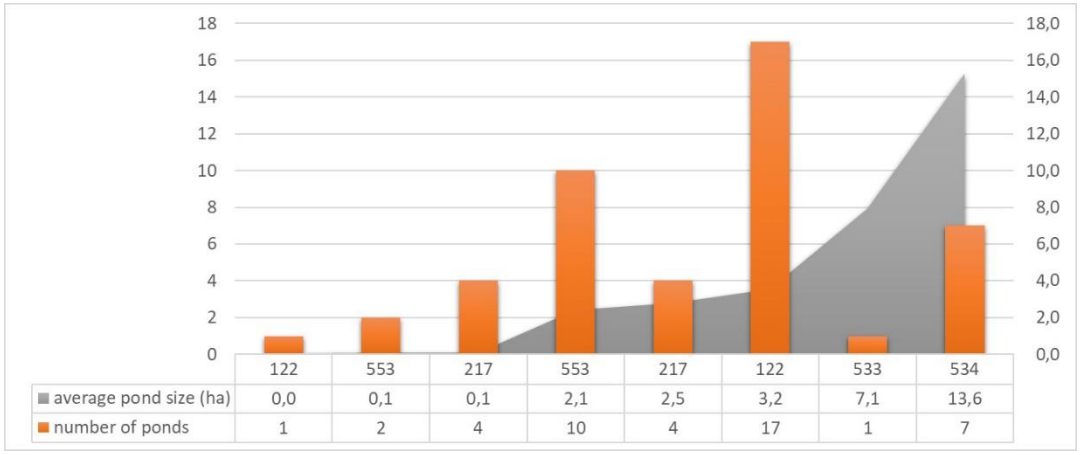

Figure 9. Spatial and size distribution of mining ponds within water-influenced landscape character types (own edited figure)

We analyzed the average size of mining ponds within the landscape character types, characterized by water dominance. The average size of mining ponds ranges from 0.1 to 102.5 hectares. The majority of mining ponds within the water-dominated landscape character type ranges in size from 7 to 18 hectares. **Figure 8** shows that the most common mining pond size within the water-dominated landscape character types is 18.5-18.7 hectares and these are classified into the "Pond landscape (421)" landscape character type. Among the largest mining pond sizes, around 80 hectares is a common average size category, these are classified into the "Water-dominated mosaic plain landscape (431)" landscape character type (**Figure 8**). Within the water-influenced landscape character types (**Figure 9**), the average mining pond size ranges from 0.1 to 13.6 hectares. The most common average mining pond size is 3.2 hectares, these are found in the "Agglomeration urban landscape on the waterfront" landscape character type. Within the water-independent landscape character types, the average mining pond size ranges from 0.1 to 9.2 hectares. Here, the most common average mining pond size ranges from 4.7 to 4.8 hectares, these are located within

"Urban landscape on plains" or "Plough-dominated homogeneous flatlands" landscape character types.

The results show that approximately 10 hectares are the limit above which the presence of mining ponds plays a more significant role in defining landscape character type areas.

6. Discussion and Conclusion

The analysis of the distribution of mining ponds by landscape character types and the characterization of the water-dominated areas resulted that only the presence of larger mining ponds with an area of more than 10 hectares or mining pond systems determine the landscape character classification regarding to the Hungarian landscape character methodology. Due to the presence of mining ponds forming large pond systems, two-thirds of the mining ponds' area is classified as "Watery landscape" landscape character type or is located in areas of water-dominated landscape character type. The majority of their water surface is located in areas classified as 'Water-dominated mosaic plain landscape' and 'Pond landscape'. In the case of the 'Water-dominated mosaic plain landscapes', the role of mining ponds is particularly important in determining the landscape character, with 14.5% of their total area covered by mining ponds (mostly gravel mining ponds). This result highlights the landscape-forming and landscape-character-modifying role of gravel mining. However, the presence of smaller (less than 10 hectares) mining ponds does not affect the water dominance of the landscape character classification, as indicated by the result that almost one-third of the total mining ponds' area is classified as a non-water-bound landscape character type. The analysis in terms of the quantity of mining ponds (number of pieces) even more proofs this result: due to a large number of small, separately located mining ponds, 83% of them are located in areas classified as non-water-bound landscape character types, even though mining ponds are mostly assessed as significant landscape character features during field observations.

The results presented in this article, due to the limitations of publication, represent only a part of our research on the role of mining ponds in defining landscape character. In addition to these results, our analyses also focus on the differences between mining ponds with open water surface and marshed surface related to the classification of landscape character types. Our research is also trying to define the relationship between the type of extracted raw materials and the landscape character type, as well as the topographical conditions of the landscape surrounding the mining ponds and its role in the landscape character. Statistical methods (e.g. cross-tabulation analysis) provide further opportunities for more precise detection of relationships between the databases produced in this research.

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