

# The Role of Mining Ponds in the Hungarian Greenway Network

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## Abstract

The aim of our research is to present the current state of mining ponds, wetlands (created by mining activity in Hungary) and to give support to the mining ponds' nature protection importance and their role in green infrastructure.

This research topic is very important, partly because of the lack of data related to mining ponds, but also because wetlands and their connecting blue and green infrastructure are playing a more important role today in reducing the effects of climate change.

A GIS analysis was made using data from the national mining register, the CORINE Land Cover and Agricultural Parcel Identification System base map, non-motorized vehicular route data, and maps of the national nature protection areas.

As a first step of the GIS analysis, we selected those wetlands in Hungary that were created by mining activity. With the help of density-analysis, we visualized the national distribution of mining ponds. As a second step, we compared these identified mining ponds with the protected natural areas of Hungary, and then we analyzed their exploration with greenways. We investigated the connection between size, raw material type, age, and the potential for tourism, religious pilgrimages, horseback riding and bicycling, as well as nature protection.

Mining activities represent a paradox among environmentally-destructive land use activities. In most cases, the extraction of raw materials below the water-bearing level causes huge damage to the landscape. As a result of this, natural resources have been lost and continue to be destroyed. At the same time, these constructed mining ponds represent significant landscape value and recreational potential. Their natural value is demonstrated by the results of our research, which found that 21.85% of mining ponds are part of some nature protection designation (National Parks, Protected Landscape Areas, National Nature Reserve areas, Natura 2000 Areas and the National Ecological Network). According to our GIS analysis, 34% of mining ponds are incorporated into greenways in Hungary.

In the case of proper usage and landscape rehabilitation, mining ponds – due to their nature protection values and beneficial landscape features – are mostly suitable or can be made suitable for being destination areas and stopping points of greenways.

## **Introduction**

About 2% of Hungary's 93 000 km<sup>2</sup> area consists of standing waters. 75% of these standing waters are artificial ponds or lakes (dammed reservoirs in valleys or round dammed reservoirs and mining ponds). (Web ref. 5) Since the implementation of river flood control projects, the formation of inland waters and the establishment of reservoirs and mining ponds have created new water surfaces.

The national state of mining ponds has not been assessed in Hungary. Mining authorities register only the mining sites; they do not keep records about spatial location of the mining pits, their number or their surface area. Water datasets do not include the origin of mining activity or the reedy and marshy mining ponds, and they contain different data about standing waters and their surface coverage. Two authoritative scientific works confirm this situation well. The recently-published National Atlas of Hungary (Kocsis, 2015) and the situation assessment survey of National Water Management Plan (Web ref. 5) include significantly different data for mining ponds and standing waters. The National Atlas estimates the number of standing waters in the country at 1,200, while the National Water Management Plan mentions 7,587 standing waters, lakes and wetlands (Web ref. 5). Of these, 828 standing waters reach the lower limit of the independent water body category (0.5 km<sup>2</sup> or 50 hectares). The lack of data and uncertainties justify our choice of this research subject.

The topic also has current relevance because of the increasing role of water surfaces, wetlands and the associated green infrastructure in mitigating the impacts of greenhouse effects. In this context, the role of mining ponds has become more important and appreciated (Módosné, 2016).

In Hungary, there are a large number – more than 16,000 – of damaged areas resulting from mining activity (mining pits, waste-heaps and mining ponds), which subtract significant areas from biologically active surfaces (Csima, Módosné, 2014). Mining ponds, however – as a result of their spontaneous succession – shift back to green infrastructure relatively quickly.

The analysis of the relationship of mining ponds and greenways is a relevant topic, because mining ponds can be potential target of the greenway network. Mining ponds have natural-landscape values and wetland and recreational role (e.g., fishing ponds, swimming lakes/beaches, ponds for sport activities etc.). The mining ponds can become valuable elements of the greenway network in the case of proper reutilization and landscape rehabilitation, so the results of the research are useful for application in the field of landscape planning.

Many landscape analyses (e.g., study plans, thesis, master plans at Szent István University, Faculty of Landscape Architecture) have been conducted at the local and regional level regarding the nature protection and recreational such as ecotourism role of mining ponds, but a national overview has not yet been undertaken. Therefore, our research aims to provide a national situation assessment of these landscapes.

## **Background and Literature Review**

Greenways are multifunctional trails, which are created for people to explore in non-motorized ways, typically by hiking, horseback riding or bicycling. Greenways can be:

- routes along natural formations used for recreation

- near-natural corridors connecting residential areas
- recreational green areas in or around settlement areas, which can be used for walking or cycling. (Web ref. 2)

Their basic characteristic is that their route is strongly associated with green infrastructure. In Hungary the assigned hiking trails, religious pilgrimage, horseback riding and cycling routes can be classified as potential greenway trails. In this way, in our research we compared these non-motorized vehicular trails with the location of mining ponds and analyzed their connections.

There are three major types of greenways in Central and Eastern Europe: long-distance greenways, local greenways, and urban greenways (Web ref. 2). These types are relevant for comparison with mining ponds.

Europe's states have developed their own greenway concepts with regard to geographical, settlement structures, economic and cultural characteristics. There are many cross-country greenways that have Europe-level importance (Web ref. 3):

- Amber Trail from Budapest to Krakow (Hungary, Slovakia, Poland)
- Krakow-Moravia-Vienna Greenway (Poland, Czech Republic, Austria)
- Brno-Vienna Greenway (Czech Republic, Austria)
- Green Bicycle – East Carpathian Greenway (Poland, Slovakia, Ukraine)
- Prague-Vienna Greenways (Czech Republic, Austria)
- Moravia Wine Trails (South Moravia, Czech Republic)
- Peace Trail – Via Pacis Pannoniae (Serbia, Croatia)

However, none of them include mining areas as destinations (Web ref. 1).

In many parts of the world examples can be found of local and urban special greenway concepts that integrate mining pits, mining ponds into the recreational and tourism system. A good example for this is the gravel mining ponds system along the German segment of the Danube River – between Ulm and Donauwörth. The mining ponds between pedestrian and horseback riding routes offer a variety of recreational opportunities, including swimming, water sports and other active-passive recreational forms (Web ref. 4).

## **Goals and Objectives**

The goal of this study is to give a national overview (using GIS) regarding:

- the location and characteristic parameters (quantity aspects, surface area, size, age, specifying by raw material type) about water surfaces, wetlands as a consequence of mining activity
- the nature values and nature protection role of mining ponds
- the role of mining ponds taking part in green infrastructure
- the ecotourism and recreational role of mining ponds and their exploration by hiking trails, pilgrimage routes, horse riding and cycling routes

## Methods

In our research, we investigated the **qualitative** and **quantitative** aspects of mining ponds, as well as their role in natural protection and ecotourism using GIS methods. ArcGIS 10.2 software was used for the analysis.

In the situation assessment, we focused on mining ponds that have been created in the last 50 years (between 1958 and 2018), and also wetlands (open water-surfaces, reeds, marshes) created as a result of mining activity. In Hungary there was no integrated national mining inventory until 1958, so no previous data was available. We used the following **data files** for our GIS analysis:

- The databases of the Mining and Geological Survey of Hungary (MBFSZ) related to mining sites, including their location, surface coverage, status (functioning or abandoned), the type of extracted raw material, and the date of extraction (mine opening and mine closing dates). The mine register does not include any information about water surfaces. (MBFSZ, 2019)
- Databases of CORINE Land Cover, Agricultural Parcel Identification System (MePAR) (Web ref. 6, 10)
- GIS data files of hiking trails, pilgrimage routes, bicycling and horseback riding routes (Web ref. 7, Web ref. 8, hiking trails and OpenStreetMap open data services)
- The national GIS database of nature protection areas (Web ref. 9)

Our analysis is based on the **processing and comparison of the GIS and mapping databases** listed above. We analyzed the connection between size, raw material type, time factor (time after mine closing) and support of tourism, hiking trails, pilgrimage routes, cycling and horse riding, as well as nature protection areas.

As a first step in the **GIS analysis**, we compared the area of abandoned solid mineral mining sites and the actively-functioning mineral mining sites with the landcover of the base maps. In this manner, we selected those standing waters and wetlands which were created by mining activities. We then processed the mining ponds' typical parameters and summarized them in a chart format.

To represent the national spatial dispersion of mining ponds, we created a **map based on dominance analysis**, (the so-called "density map"), which analyzes a 1.5 km buffer around each cell. In this way, the map shows those areas where mining ponds and wetlands are dominant (**Figure 4**).

The second step in the GIS analysis compared these sorted mining ponds and wetlands (reeds, marshes) with the nature protection areas in Hungary. In this section, we examined National Parks, Protected Landscape Areas, National Nature Reserve areas, Natura 2000 Areas and the National Ecological Network. We analyzed the relationship between mined raw materials and protected areas.

In the third step of the GIS analysis, we examined the potential connection between mining ponds and greenways. We analyzed whether in the 0.5 kilometer to 2,000 kilometers wide area surrounding mining ponds and wetlands there are any assigned hiking trails, pilgrimage routes, cycling or horseback riding routes.

## Results

### The surface area of mining ponds and their distribution of raw material

According to our calculations, the **surface area** of open water-surface mining ponds and wetlands created between 1958-2018 as a result of mining activity, is approximately **20,470 hectares** (204,700 km<sup>2</sup>) in Hungary. Compared to the total area of the country, their proportion is only 0.2%. However, compared to the area of standing waters in Hungary, their proportion is **12.1%**, which is significant. **35.74%** of the wetlands resulting from mining activity have **open water-surface**. For the remaining 64.26% of mining ponds, the open water-surface has disappeared due to the expansion of reeds and marshes (**Figure 3**). The number and surface area of open water-surface mining ponds is constantly changing because of the spontaneous succession processes, the opening of new mines, and nowadays, the more frequent refilling of mining pits.

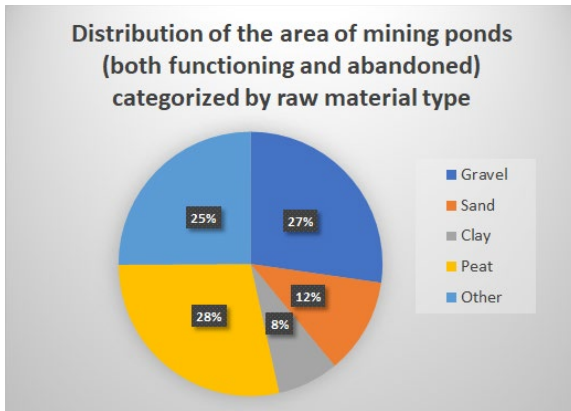
Based on the available data, we were able to identify 1,024 abandoned or functioning mining sites on which mining ponds or wetlands have been formed. Most mining ponds are the result of peat mining (58.11 km<sup>2</sup>, 28%) and gravel extraction below groundwater level (55.85 km<sup>2</sup>, 27%). In addition, there are also mining ponds created by clay mining (15.36 km<sup>2</sup>, 7.5%) and sand mining (24 km<sup>2</sup>, 12%) (**Figure 1**). Many mining ponds are the result of outcrop ore mining (**Photo 1**) and quarrying. There are other types too, such as deep-working coal mines which have resulted in standing waters, such as in the vicinity of Várpalota, where there are several sinking ponds in a more than 2 km<sup>2</sup> area (**Photo 3**).

The relationship between size, status (functioning/abandoned), and raw material type of mining ponds and their water surface (open, reedy) is displayed in **Figures 1, 2, 3** and **Table 1**.

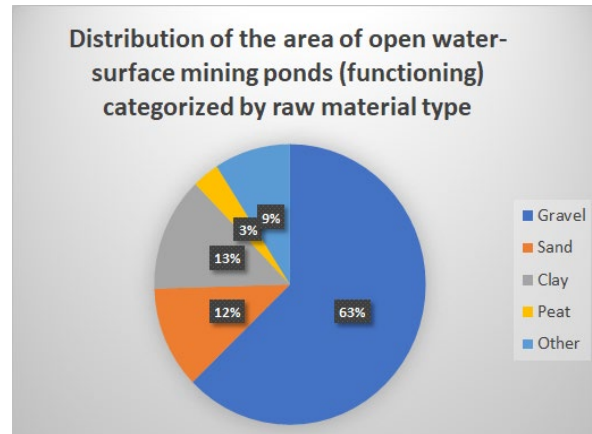
Distribution of the surface area of mining ponds categorized by raw material type and mining status (functioning/abandoned)						
Raw material type	Abandoned mining sites		Functioning mining sites		Total area of external surface (km <sup>2</sup> )	Percentage distribution (%)
	Area of open water-surface mining ponds (km <sup>2</sup> )	Area of reedy mining pits (km <sup>2</sup> )	Area of open water-surface mining ponds (km <sup>2</sup> )	Area of reedy mining pits (km <sup>2</sup> )		
Gravel	11.7723	5.5578	28.6395	9.8837	55.8533	27.29
Sand	6.5026	5.2267	5.3738	6.8929	24.00	11.72
Clay	1.8711	3.2240	6.0226	4.2388	15.3565	7.50
Peat	2.8830	18.359	1.4593	35.4104	58.1117	28.39
Other*	4.4936	14.7078	4.1474	28.0362	51.385	25.10
<b>All type</b>	<b>27.5226</b>	<b>47.0753</b>	<b>45.6426</b>	<b>84.462</b>	<b>204.7025</b>	<b>100</b>

\* Note: Other: stone (dolomite, limestone), lignite, ore, coal mine

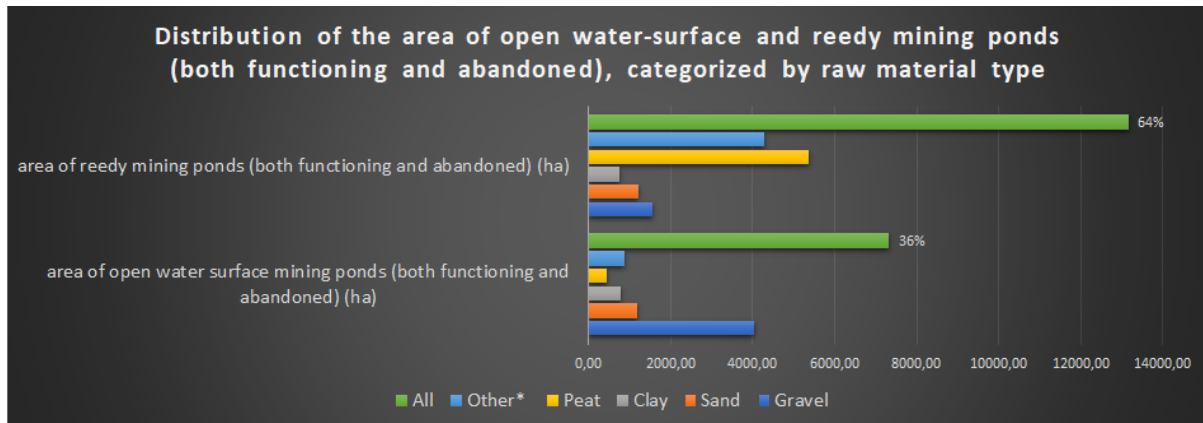
**Table 1.: Distribution of the surface area of mining ponds categorized by raw material type and mining status (functioning/abandoned) (compiled by the authors)**



**Figure 1: Distribution of the area of mining ponds (both functioning and abandoned) categorized by raw material type (compiled by the authors)**



**Figure 2: Distribution of the area of open water-surface mining ponds (functioning) categorized by raw material type (compiled by the authors)**



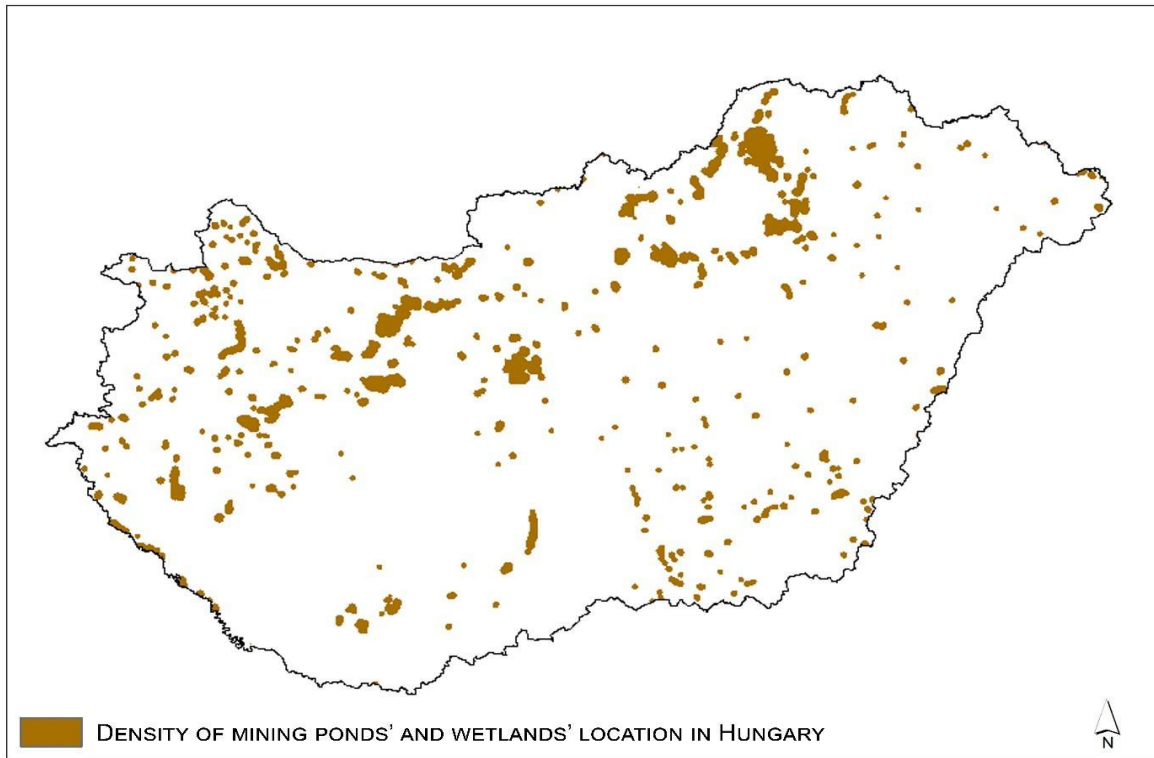
**Figure 3: Distribution of the area of open water-surface and reedy mining ponds (both functioning and abandoned), categorized by raw material type (compiled by the authors)**

We can state that the gravel mines (55%), sand (16%) and clay (11%) mines possess the greatest amount of open water-surface among mining pond types. Rapid succession and reed formation affect mostly peat mining ponds. It is interesting to note that among ponds resulting from quarrying and other raw material mining (such as stone, ore, coal), there are a large number of wetlands, especially in coal mine pits (**Photo 3**), (**Figure 3**).

#### National distribution of mining ponds

**Figure 4** shows the aggregated **national distribution** of mining ponds by dominance analysis. In examining the spatial location of mining ponds, the main industrialization axis, trending in the SW-NE direction, stands out. Gravel and sand mining ponds are most dense in the area south of Budapest, where hundreds of hectares of lake systems have been formed near Délegyháza, Bugyi, and Dunavarsány (**Photo 4**), (**Figure 13**). These are used for recreation and the non-motorized vehicular network also crosses them. Extended pond systems can additionally be found along the Nyékládháza-Miskolc-Kazincbarcika axis and the Dráva River. A contiguous pond system has developed, connecting the following areas as a result of

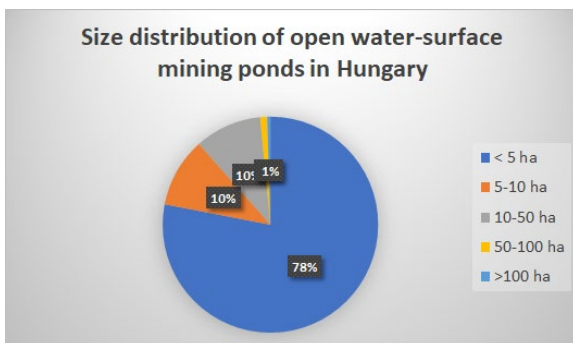
peat mining: the “Red marsh” region in Császártöltés (8.17 km<sup>2</sup>); Nádasdladány (5.5 km<sup>2</sup>); and the Vindornya valley (3.2 km<sup>2</sup>). (Hubayné, 2005 a, b, 2017)



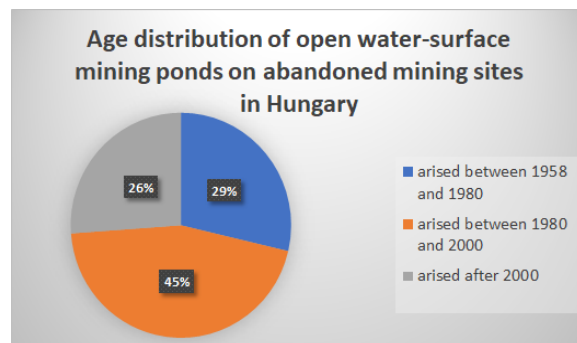
**Figure 4: Density of mining ponds and reedy wetlands as a result of 1.5 km dominance analysis in Hungary (compiled by the authors)**

Size of mining ponds

There is a large variation in the size of mining ponds identified as a contiguous patch: **it ranges from 0.5 hectares to 273 hectares**. 78% of the open water-surface mining ponds are **less than 5 hectares**, and only 1.5% exceed 50 hectares. The size distribution of open water-surface mining ponds is displayed in **Figure 5**.



**Figure 5: Size distribution of open water-surface mining ponds in Hungary (compiled by the authors)**



**Figure 6: Age distribution of open water-surface mining ponds on abandoned mining sites in Hungary (compiled by the authors)**

### Age of mining ponds

In terms of spontaneous natural regeneration of mining ponds, as well as their natural resource values and ecotourism-recreational potential, **the time after mine closing** is a determining factor (**i.e., the age of mining ponds**). Under undisturbed conditions – depending on the depth of the water – the open water-surface of mining ponds can be reduced by as much as one fourth in 15 years, as reeds are expanded and pond filling occurs. These processes are illustrative of abandoned, unused ponds – especially peat mining ponds (Hubayné 2005a, b, 2017, Szurdoki 2017) and so-called sinking ponds. Because of the vegetation established as a result of spontaneous or supported succession, mining ponds can become valuable elements of blue or green infrastructure, and can be integrated into the greenway network (Kató, Módosné 2016, Varga 2018).

The age distribution of abandoned mines (calculated from the time of mine closing) can be seen in **Figure 6**. It shows that almost half of the abandoned “wet” mines (45%) have arisen between 1980 and 2000.

### Nature protection importance of mining ponds

In Hungary, mining ponds are used for fishing, fish farming, recreation (swimming or boating, for example) and as wetlands for nature conservation purposes, as well as reed management. In many areas, vacation homes and other structures have been built along the shoreline of ponds, resulting in serious land use conflicts. An example of this can be seen in the area of peat mining ponds adjacent to Dunakeszi, near Budapest (**Photo 5**).

Mining ponds, regardless of their usage, play a role in wetland. **Their natural-landscape values are reflected by the extent to which they are under nature protection.** For that reason, we analyzed the quantitative parameters of mining ponds related to nature protection areas by conducting a GIS comparison of mining ponds, wet mining pits and nature protection areas. The analysis of nature protection areas does not cover ex lege (which means protected due to one single law) protected mires.

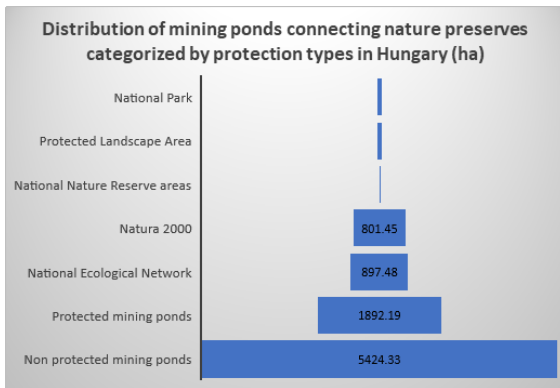
According to our calculations, **21.85 %** of mining ponds and wetlands arising in the last 50 years **are covered by some nature protection designation in Hungary**. 4.2% (8.65 km<sup>2</sup>) of the mining ponds' total area is part of national nature protection areas (National Parks, Protected Landscape Areas, National Nature Reserve areas). An additional 23.42 km<sup>2</sup> (11.4%) of abandoned mining ponds is protected as part of Natura 2000 Areas, and 26.98 km<sup>2</sup> (13.2%) is part of the National Ecological Network (**Table 2, and Figures 7, 8, 9, 10**).



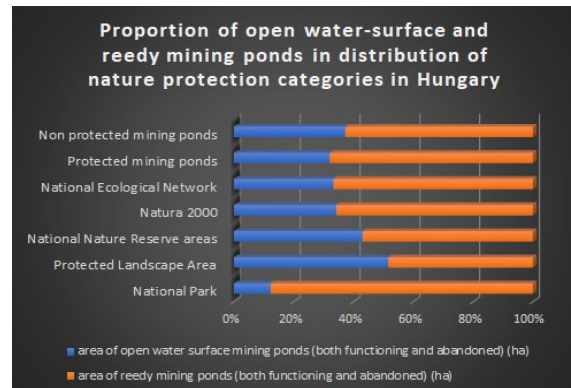
Distribution of mining ponds* connecting nature preserves categorized by protection types in Hungary				
Protection category	Area of mining ponds under protection (km <sup>2</sup> )	Area of reedy mining ponds under protection (km <sup>2</sup> )	Total area of mining ponds under protection (km <sup>2</sup> )	Percentage distribution of protected mining ponds compared to total (%)
National park	0.7721	5.5274	<b>6.2995</b>	<b>3.1</b>
Protected Landscape Area	0.9075	0.8505	<b>1.758</b>	<b>0.9</b>
National Nature Reserve areas	0.2530	0.3352	<b>0.5882</b>	<b>0.3</b>
Natura 2000	8.0145	15.4041	<b>23.4186</b>	<b>11.4</b>
National Ecological Network	8.9748	18.0051	<b>26.9799</b>	<b>13.2</b>

\* Note: Mining ponds formed between 1958-2018

**Table 2: Distribution of mining ponds connecting nature preserves categorized by protection types in Hungary (compiled by the authors)**



**Figure 7: Distribution of mining ponds connecting nature preserves categorized by protection types in Hungary (compiled by the authors)**

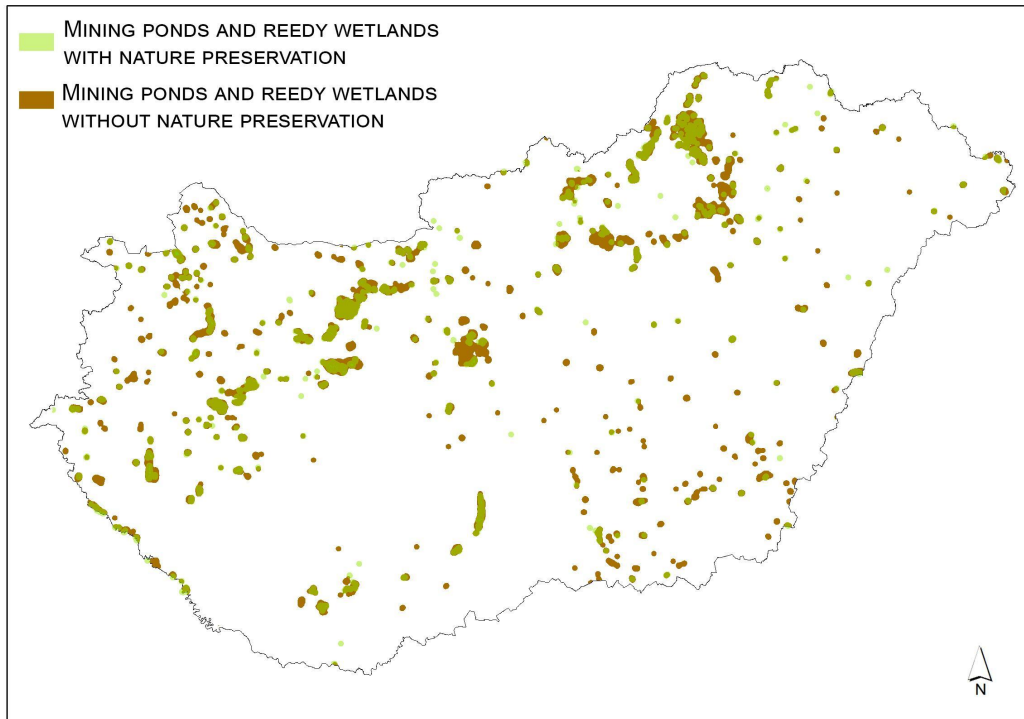


**Figure 8: Proportion of open water-surface and reedy mining ponds in distribution of nature protection categories in Hungary (compiled by the authors)**

Due to their rapid natural succession and regeneration, the abandoned shallow mining ponds transform into marshes within a few decades after mining activities cease. They become completely reedy and lose their open water-surfaces. (According to our calculations, only 35.74% of wet areas resulting from mining activity are open water-surface ponds – see **Figure 3**). This phenomenon is mostly characteristic of peat

mining ponds in Hungary. In our analysis, we compared the nature protection role of open water-surface and reedy mining ponds (**Figures 9 and 10**).

Peat-mining ponds have unique features. More than one-third function as wetlands, and 20-40 years after mining ceases, they become exciting, diverse habitats (refugiums), rich in landscape values. They fill a unique role in the preservation and new formation of marsh communities. Many rare and endangered species of flora and fauna – which have Europe-level importance – have taken refuge in these peat mining sites (Hubayné, 2005a, b, 2017).



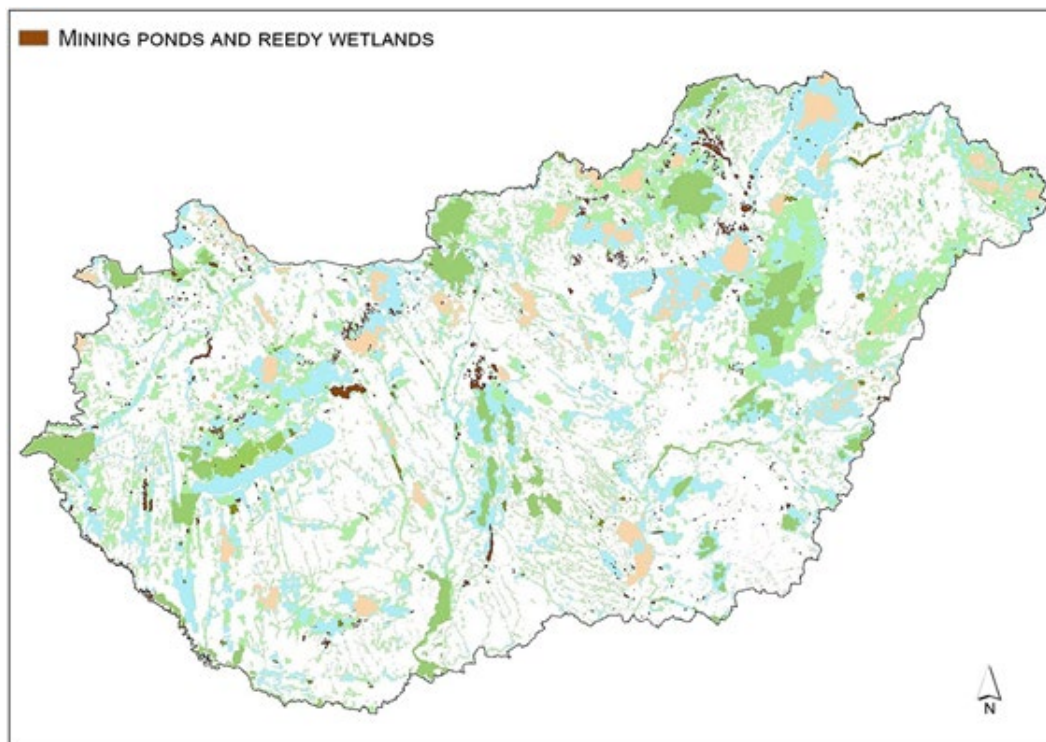
**Figure 9: Nature protection importance of mining ponds in Hungary (using 1.5 km dominance analysis) (compiled by the authors)**

#### Ecotourism role of mining ponds and comparison with greenway network

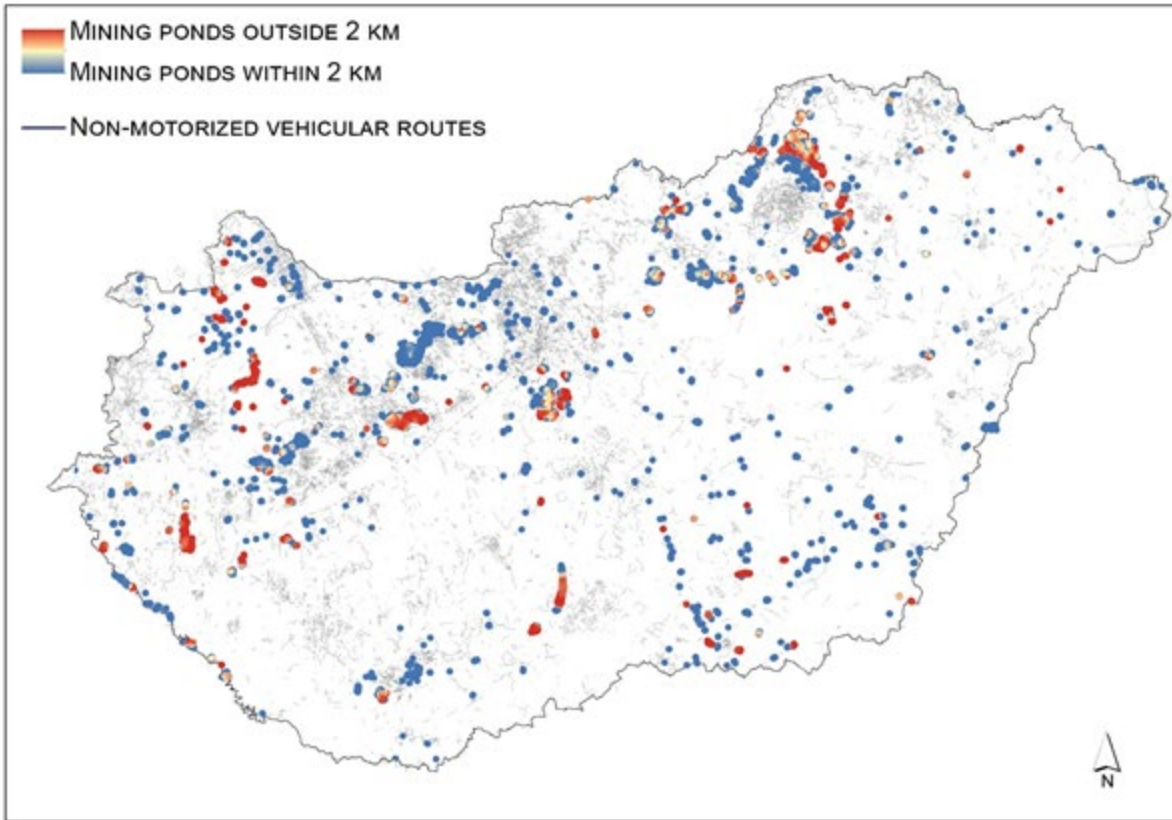
The main aim of our research was to compare the potential greenway network and the spatial location of mining ponds. During the analysis, we considered tourist, religious pilgrimage, horseback riding and bicycling routes as greenways or as potential non-motorized vehicular routes for greenway shaping (henceforward, “potential greenway”). **Figure 12** illustrates the results of our GIS analysis. According to the analysis, **34% of mining ponds can be considered accessible by potential greenways in Hungary**. This means that one-third of the mining ponds are located within 0.5 km of pedestrian routes and within 2 km of equestrian and bicycling routes. 66% of mining ponds are not considered part of the trails listed above (i.e., none of these routes were located within 2 km). The designated non-motorized routes and the mining ponds which can be accessed by them can be seen on **Figure 11**.

Due to the mining ponds’ nature values and advantageous landscape features, a number of them are popular locations for nature preservation and ecotourism. A few highlights of the many Hungarian examples follow. A visitor center, observation tower and nature trail are located at the former iron ore

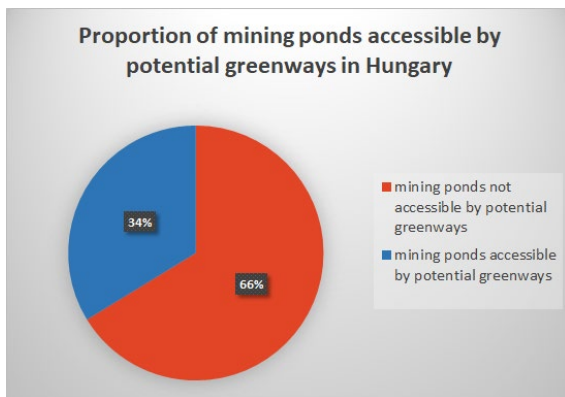
mine in Rudabánya (**Photo 1**). The lake in Megyer-hill was once a medieval millstone mine, but today it is a popular ecotourism destination, where a nature trail introduces the lake to the visitor. Additional nature trails, which reveal the living resources of peat mines, are found at Lake Király in Hanság (**Photo 6**), Lake Kolon in Izsák, in the Vindornya valley, and in the area of so-called “Red marsh” in Császártöltés (Hubayné, 2017). The mining pond in Tarcis is located in the area of a world heritage site which is a popular tourist destination (**Photo 2**) (Módosné, Csima, Kertész 2017).



**Figure 10: Connection between mining ponds, reedy wetlands and designated nature preserve areas in Hungary (compiled by the authors)**



**Figure 11: Connection between potential greenways and mining ponds in Hungary (compiled by the authors)**



**Figure 12: Proportion of mining ponds accessible by potential greenways in Hungary (compiled by the authors)**



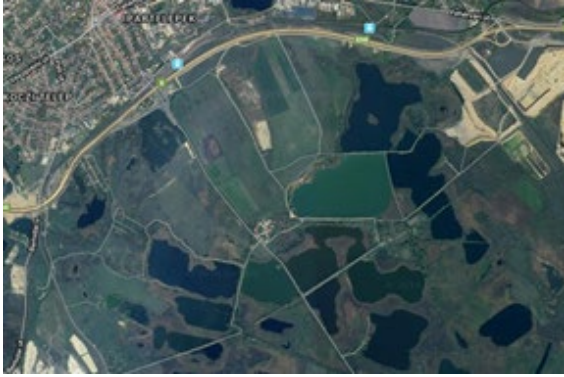
**Figure 13: Tourist and pilgrimage routes around gravel mining ponds in Délegyháza (Web ref. 8)**



**Photo 1: A visitor center, observation tower, and nature trail are located in the area of the former iron ore mine in Rudabánya (Photo by Hubayné, 2016)**



**Photo 2: Naturally revegetated mining site in Tarcal, in the area of a world heritage site (Photo by Módosné, 2017)**



**Photo 3: Naturally revegetated reedy mining sites in the vicinity of Várpalota (GoogleEarth, 2019)**



**Photo 4: Gravel mining pond in Délegyháza, built-in and also used for recreation (Photo by Módosné, 2014)**



**Photo 5: Peat mining ponds surrounded by vacation cottages in Dunakeszi (Photo by Károly Kertész, Dunakeszi MÁV)**



**Photo 6: Lake Király: a priority protected peat mining pond in Hanság. It is the destination of a nature trail.**

## Discussion and Conclusion

Mining activities represent a paradox among environmentally-destructive land use activities. In most cases, the outcrop extraction of raw materials causes huge damage to the landscape. At the same time, constructed mining ponds represent significant landscape value and recreational potential. Their natural value is demonstrated by the fact that 21.85% of mining ponds built-in the last 50 years are part of some nature protection designation, according to our results.

Their recreational potential and ecotourism role is confirmed by the fact that 34% of them are accessible by tourist, pilgrimage, equestrian and bicycling routes. In the case of proper reutilization and landscape rehabilitation, mining ponds – due to their nature values and/or beneficial landscape features – can be potential areas for developing greenways – not just in Hungary, but in other locations as well. While our analysis investigates the state of Hungarian mining ponds, the described landscape-transforming processes and other phenomena are also relevant in the European context.

The results of our research can be integrated into the methodology of greenway network planning and post-mining land use planning, as well as urban development and land use planning in mining areas.

## Acknowledgements

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