

LANDSCAPE TRANSFORMATIONS ON MOHÁCS ISLAND FOLLOWING RIVER REGULATIONS

TRANSFORMACIJE KRAJOLIKA NA RIJEČNOM OTOKU MOHAČ NAKON REGULACIJE RIJEKE

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ABSTRACT

Mohács (or formerly Margitta) Island is a river island of the Danube, located in the southern part of the Great Hungarian Plain, partly extending to Croatia. River regulations in the 19th century and related inland water drainage works reshaped the landscape pattern and farming systems of Mohács Island. First, second, and third military survey maps and a lesser known detailed survey, the so-called Danube mappation, were utilized for the reconstruction of the landscape in the 18th and 19th centuries. The scanned map-sheets were digitized and converted into a vector landscape map. These results were compared with a landscape map drawn on the basis of the 1952 topographic map. Our studies were supplemented with ethnographic data.

As a result, we proved that the proportion of wetlands and riparian forests extremely reduced (Table 1, Fig. 8). At the same time, the rate of arable lands increased from zero to seventyone percent until the middle of the 20th century. Although, the process was not linear. By the end of the 19th century the island became very swampy which can be seen on our generated map from the third military survey (Fig. 6, Table , Fig. 8). Moreover, our maps present how many different riparian habitats were able to be found on the island and for how long. Finally, it can be stated which are the areas where inland water damage is expected and which are most suitable for arable cultivation.

Keywords: Mohács Island, river regulations, landscape transformation, GIS

Ključne riječi: riječni otok Mohač, regulacija rijeke, transformacija krajolika, GIS

INTRODUCTION

Our goal was to get an answer to the question what was the degree of landscape transformation from the end of the 18th century until the beginning of the twentieth century (when the process became completed with the evolving drainage infrastructure). In addition to preparing map representations, we also collected references from the literature and examined relevant results from several scientific disciplines. Furthermore, besides ethnographic and historical references, we also examined the mapping files containing landscape information of the National Archives.

Settlement structure evolving was also the target of our investigations. Selected areas were studied in detail and charts were plotted. The transformation of Mohács Island is a very complex process, which requires not only hydrological, but also geographical, topographical, historical, economic historical, ethnographical and biological studies.

The driving force behind the transformation was river regulations, of which main objectives were to conquer agricultural land, develop fairways, and avoid the formation of ice floods. The summary works of Ihrig D. (1973) and Tóry K. (1952) provide an overview of the whole process of regulations of the Danube. ERDŐSI F. and LEHMAN A. (1974) gave a complete description of Mohács region including Mohács Island. Other researchers of geography dealt with that area as a part of large summary descriptions of landscapes (MAROSI S. - SOMOGYI S. 1990, DÖVÉNYI Z. 2010), but they also applied modern landscape assessment methods (LÓCZY D. 2008, HERVAI A. - LÓCZY D., 2009).

One of the central topics of the research was the processing of earlier maps (Lazarus décor, Marsigli, Müller, Pávai, Karpe) and related scientific works. FALUDI G. and NEBOJSZKI L. (2008) comprehensively presented maps depicting the island, but also investigated the historical changes of the waters. GLASER L. (1933) and DÓKA K. (1986) examined the Hungarian related maps of the Karlsruhe Archives. Scientific work has also been done on the evaluation of military surveys (JANKÓ A. 2007) and Danube mapping (DÓKA K. 2006).

Historical science is primarily related to the study of settlements and place-names (IVÁNYI I. 1906, GYÓRFFY Gy. 1966, PESTI J. 1982). Studies in economic history, which investigate the economic consequences of certain profit-making and land use methods (MOLNÁR G. 1991, 1993a, 1993b, ZÓKA P. 2013), or even the economic significance of water-saving associations (KENESSEY B. 1931) are important sources.

Naturally, local history works also contain valuable information in terms of landscape transformation and land use (FÖLKÉR J. 1900, KOSZTA L. 1993, KONKOLY S., 2014). Among the ethnographic experts, ANDRÁSFALVY B. (1973) identifies oxbow lake fish management as an essential economic resource of the people of the Danube region.

ANDRÁSFALVY B. regards social change as a direct consequence of the utilization patterns transformed after the regulation works. His studies specifically concern Mohács Island, and in a separate study he dealt with animal husbandry in the area (ANDRÁSFALVY B. 1970).

The fauna and flora of the island has long been researched by biologists (BOROS Á., 1922, KEVEY B. et al, 1992), besides wetlands, forests are a priority investigation topic (KOVÁCS Gy. - DEME T. 2008, BIRÓ M. 2008). Research related to Mohács has been conducted using an interdisciplinary approach combining physical geography, hydrography and landscape reconstruction also relying on archive historical data (PAP N. et al. 2019).

METHODS

To reconstruct landscape change over more than a hundred years of flood and inland water drainage, four map representations were available. The first military survey map was made between 1782 and 1784. Landscape elements are not yet readable in detail from this map. Furthermore, the mapping was also relatively inaccurate (e.g. Lake Riha's position; Fig. 3).

The next map is the mappation of the Danube. The mapping period for the southern part of the Danube region was the 1820s and 1830s. Mapping of the right branch area reached Mohács Island in 1825 (DÓKA K. 2006), while the Nagybaracska branch was mapped quite late, in 1836. From this

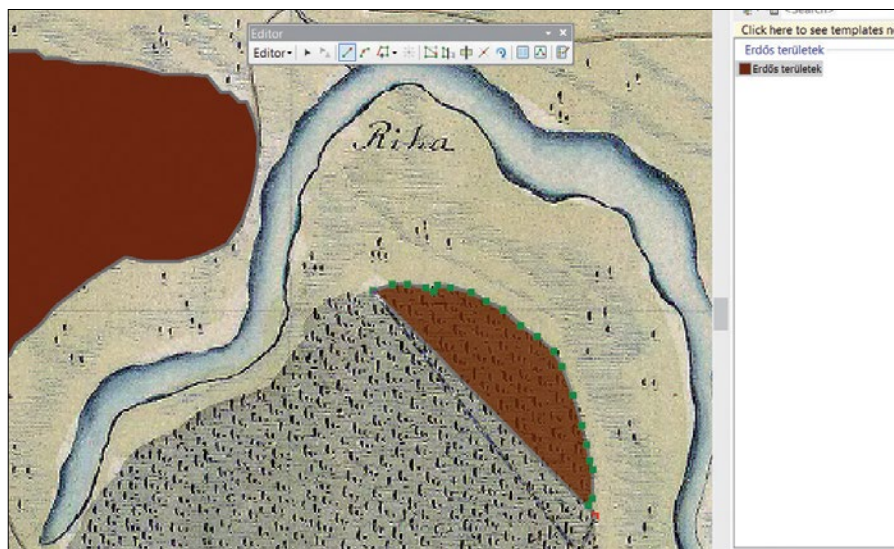


Figure 1. Polygons digitized from the first military survey map of Mohács Island (1782-1785)

period we have a fairly accurate and detailed landscape map, as the purpose was the process primarily to transform the landscape.

The second set of military maps from 1858 is our third snapshot to examine the landscape (JANKÓ A. 2007). It was less detailed than the Danube mappation, but still implied much more information than the first military survey map. The map sheets of the third military survey of Mohács Island were made in 1884. This map matches in details with the Danube mappation. Our reference map was the 1952 topographic map.

During our research we attempted to quantify the degree of change. The investigations were carried out using GIS tools. ArcGIS 10.4.1. was our base tool. With the help of this software first we collected the land use data from the maps (first, second, third military maps, the Danube mapping and the topography of Hungary from 1952).

The military survey maps were downloaded from Mapire.eu/en, the Danube mapping was attained from maps.hungaricana.hu. The 1952 military map with EOVS coordinate system was chosen as the base map. This map was available at Department of Geography of the University of Pécs. The maps were rotated and disassembled using Georeferencing menu tools to fit the 1952 maps, with the so-called rubber sheet stretching method (LÓCZY D. 2002).

First, we had to transform the maps into EOVS (HD 72 Unified national projection system) coordinate system for their comparability. After that for raster maps which were already in proper position Define Projection was used to transform to EOVS coordinate system. Once the maps were well resized and their appropriate coordinate system was created, the type of land cover had to be identified in order to observe changes. Thus, raster maps had to be converted into vector maps.

ArcGIS software's Editor menu was used for drawing. Point-to-point sketches of each patches to generate vector polygons (Fig. 1).

The Align to Shape function of the Advanced Editing menu was used to correct the generated objects during digitization (Fig 2.).

Once all the individual areas were marked, their exact areas had to be determined in order to be compared. For this we used the Calculate Geometry operation of ArcGIS. The Select by Attribute operation was used to sort the different surface data, then exported their attribute table to MS Excel.

We have reviewed map descriptions for Danube mapping and military maps. The descriptions of Danube mapping were copied from the application received from the Department of Ethnography of the University of Pécs.

We used A. Jankó's study (2007) for information on military survey maps and Dóka's work (2006) to interpret the Danube map. The attribute table was exported to an Excel table, where we summed up

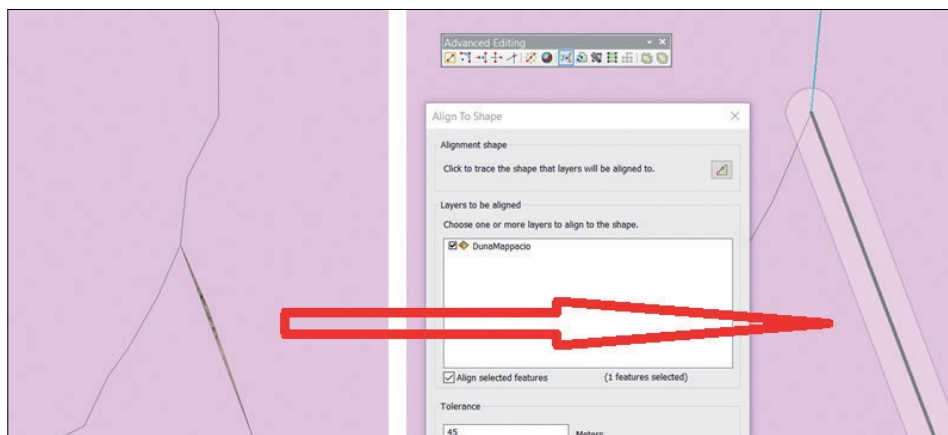


Figure 2.
Repairing
the objects
with ArcGIS
10.4.1.

the total area of different surface areas for different years. As a result, a table (Table 1) and a 3D bar-chart was produced (Fig 8.).

RESULTS

Before the regulation of the Danube, Mohács Island was fully exposed to floods and surface reshape activity of the river. Accordingly, it was only partly suitable for permanent human settlements.

During site visits related to lawsuits and border disputes Medieval settlements in the northern part of the island are known from the Zichy Codex (NAGY I. 1894), which mentions some names of places, like Lak, Vajas, Földvár, Sembecs, Paliport, Töttös, etc. These settlements also appear in GYÓRFFY Gy.'s (1966) historical geographic work about the Árpád Age.

The Island of Mohács was already less populated than the higher stages and real river terraces which were not threatened by flood. From the end of the 15th century, a series of devastating floods affected the Danube. This phenomenon and the appearance of the Ottoman Empire resulted in the disappearance of medieval settlements (KISS A.- LASZLOVSZKY J. 2013).

During the Turkish occupation, the island provided shelter for many residents. Nonetheless, the oxbow lake fish management ceased (ANDRÁSFALVY B. 1975). Thus, the landscape might have been untouched at the beginning of the modern age, even by the end of the 17th century, because of the unmanaged notches (so called »foks«, canals linking backswamps to the Danube channel) it was a waterlogged wetland. Turkish censuses already include scrubs, gardens and meadows that are in the hands of the Hungarian population of Szekcső and Mohács (BÁRTFAI SZABÓ L. 1938; PESTI J 1982). The first records of farmsteads (so called »szálláskertek«, gardens with winter accomodations) on the island date back to the time of the Turkish occupation, but it did not spread until the 18th century and began to spread in connection with grazing livestock. However, during the Turkish times, most of the island villages were destroyed.

After the expulsion of the Ottomans, it was long before the resettlement of Mohács Island. Oxbow lake farming gradually resumed along with the significance of fishing, livestock breeding and fruit production (ANDRÁSFALVY B. 1975).

Water management measures in the area can be divided into two stages: the regulation of the main branch of the Danube and the consequent flood protection, as well as canal constructions and inland water control.

In 1777 and later in 1783, the Mohács Town Council decided to replenish the Kanda Notch on Mohács Island. Thus, landscape transformation started on Mohács Island. Between the towns of Baja and Mohács, under the direction of József Beszédes, the curves of the Danube were closed by four cutoffs in 1820-21 (FALUDI G. - NEBOJSZKI L. 2008). Moreover, the Great Danube glacial floods of 1838 and 1876 necessitated further cutoffs and dike constructions.

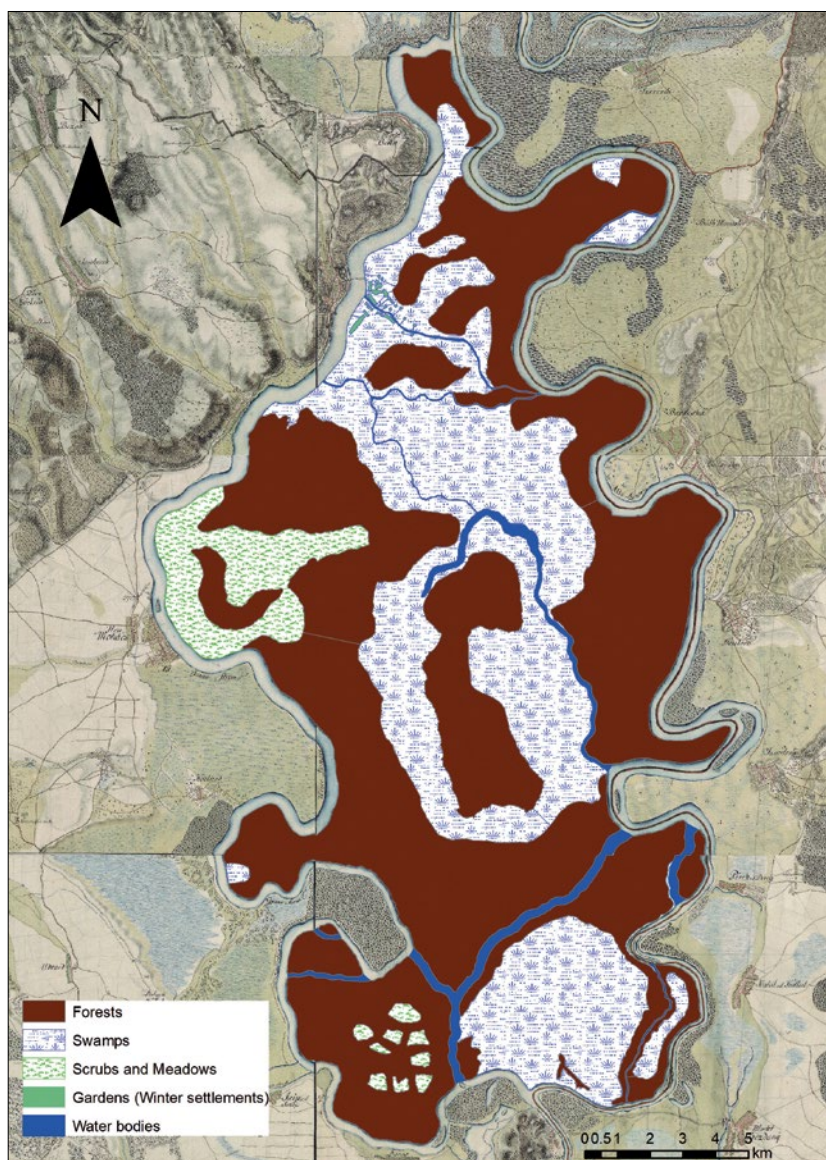


Figure 3 – Land cover map about Mohács Island around 1780 based on the First Military Survey (self-made map, source: Mapire.eu).

The residents of Mohács partially regretted this decision. Later in the 1820s and 1830s they decided to reconstruct the notches to improve the quality of wetlands (ANDRÁSFALVY B. 1975).

The first military survey took place in the 1780s. The mapping was magnified, with no minor notches or mortlakes. The accommodations appeared in a large patch near the left bank of the Szekcsői Danube. However, Lake Riha apparently still had a connection with the Baracscai Danube, but its position was certainly not well established, since it was much closer to the Mohács-Danube branch during the Danube mapping at 1825 and the second military survey (Fig. 3, Fig. 4, Fig. 5).

The map created by the first military survey was also processed geographically (Figure 3 and Table 1). According to the results, by the end of the 18th century the island was dominated by forests and swamps (92 %). By this time, oxbow lake fish management was re-established.

As far as the description of almost every map sheet is concerned, the entire island seems to be inundated during floods. Furthermore, it also appears that earlier it used to be resided, but at that time there were only farmsteads. These are marked on the map around Dunafalva.

Lake Riha is referred to as a stream in the description. Rafts can be used on the island and between the higher areas were difficult to navigate. In addition to oxbow lake fish management, animal husband-



Figure 4 - Land cover map about Mohács Island around 1825 based on the Danube mappation (self-made map, base map: maps.hungaricana.hu)

ry was also observed. High beech, oak and alder trees are described in the area (www.mapire.eu, JANKÓ A. 2007), which is typically characteristic for riparian forests.

Between 1793 and 1802, the Ferenc Canal was built under the leadership of József Kiss and Gábor Kiss. Consequently, the main part of the left bank of the Danube was linked with this canal, and the newly opened waterway made it possible to transport products cheaply from fields (FALUDI G. – NEBOJSZKI L. 2008).

Under the management Director József Beszédes four cutoffs were completed between Fadd and Mohács in 1820-1821. As a result, the course of the Danube was shortened by 33.4 km. Between 1825 and 1830 a 6.5 km long dike was built to protect the Danube branch of Szekcső and 12.5 km to protect the Danube branch of Baracska (IHRIG D. 1973).

A report from the regulation of 1825 states that 180,000 acres of land were flooded before the regulation, afterwards only 100,000 acres remained (ANDRÁSFALVY B. 1975). This means that the proportion of flooded areas was reduced from 90% to 50%. In 1825, the Mohács Town Council ordered to cut gaps to keep the oxbow lake fish management system alive.

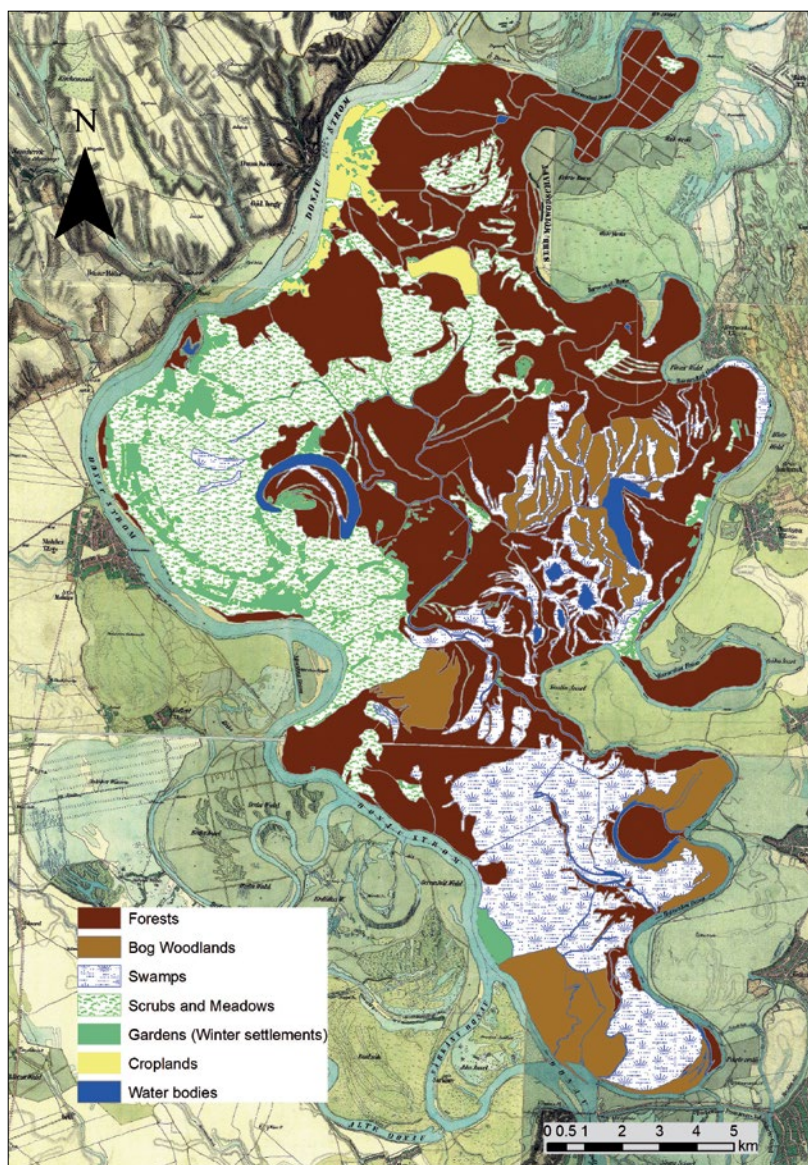


Figure 5 – Land cover map about Mohács Island around 1858 based on the Second Military Survey (self-made map, source: Mapire.eu).

Between 1823 and 1845 the Danube was surveyed and mapped (Fig. 4) by planning an accurate geodetic and landscape map for the purposes of river regulation. Most of the Mohács Island map-sheets were drawn in 1825. However, the Danube branch of Baracska was not surveyed until 1836. The studied maps and associated descriptions provide valuable information on the period between the first and second military surveys. We can obtain a much more accurate picture of types of land use than the first military survey.

The island was a system of oxbow lakes and abandoned channels. Also, the area between them was occupied by swamps, meadows, forests and bog woodlands (Table 1, Fig. 8). Proportion of wetlands reduced from 33 percent to 26 percent, nonetheless it was still significant. Additionally, on this map it is already possible to distinguish two different wetland habitats: swamps and bog woodlands. Moreover, farmsteads were evidently located in the western part of the island in large numbers, respectively field crop production was still marginal at this time. The map is very detailed, so this is the first map evidence of the extent of the lake system that can be used by the oxbow lake fish management system.

In 1836, the Mohács Town Council decided to reconstruct the oxbow lake fish management (ANDRÁSFALVY B. 1975). A 19th century forest management plan describes well-developed, naturally regenerated, closed oak, elm and ash stands in Béda-Karapancsa (KOVÁCS Gy. - DEME T. 2008).

The ice flood of 1838, which caused catastrophic destruction all along the Danube, refuted the idea of security. Between 1843 and 1852, 11 incisions were made on the basis of Beszédes plans, which meant a 96 km shortening (IHRIG D. 1973). Further work led to a shortening of 52 km until 1870.

Post-flood construction shows that defense has become more important than preserving traditional forms of farming. The work has led to a major landscape change. Much of the island has lost its natural character, and gaps were no longer allowed in the dikes to maintain oxbow lake fish management system.

The long-lasting second military survey reached Mohács Island in, when the Danube branch of Baracska was a living, natural river branch. The map of the second military survey was also processed using GIS tools (Fig. 5., Table 1).

A quarter of the area was covered by shrubs, appearing in the vicinity of the farmsteads. The proportion of wetlands was almost the same as 30 years before significant (reduced from 26% to 25%). Similarly, the share of forests almost also remained the same (increased from 44% to 45%). The relative prevalence of oxbow lake fish management is reflected in the high proportion of farmsteads. The farming of the island was mainly forest, pasture and reed (Fig. 5, Fig. 8).

In 1870 the Old Danube was closed under Szeremle. However, the Danube flood of 1876 caused enormous damage again. The flood-control dikes were ruptured at 16 places, therefore, their height was raised by 1.25 m.

In the second half of the 19th century, the Bellye manor was ruled by Archduke Albrecht and already had modern forestry management. This manor owned the southern half of the island. At this time blackberry trees were planted for silk production. The dominant tree species were pedunculate oak, shrub, hardwood, hornbeam and curled maple (ZÓKA P. 2013). Spruce, forest and black pine, common and American walnut, American oak, beech and black locust (*Robinia pseudoacacia*) were artificially planted.

The third military survey was made on the island at 1884 (Fig. 6). The notches, oxbows and lake system around Lake Földvár were still there. The eastern half of the island was occupied by swamp, marsh and groves. Due to the dams between the embankments completed by 1875, the natural runoff towards the Baracska Danube ceased. From the map it can be seen that by the end of the 19th century the island started to get wet again due to inland waters and run-off backwaters. The proportion of wetlands increased from 25-30 percent initial value to 40 percent until the end of 19th century (Table 1, Fig. 8). The island started to get swampy from the collected waters (BUZETZKY Gy. 2002).

To the north and west of Lake Riha, patches of wetlands increased. Further water management was more about draining inland waters than building new crossings and dikes.

The flood of 1897 inundated the area again. In 1899, the Minister of Agriculture ordered the establishment of the »Margitta Szigeti Ármentesítő és Belvízlevezető Társulat« (Margittasziget River Regulation and Drainage Association), whose director engineer was Szilárd Küzdényi (FALUDI G. - NEBOJSZKI L. 2008) due to the waterlogging of the island (BUZETZKY Gy. 2002). In addition to the construction of the embankment, the company also had the task of draining inland water.

In 1904, the Karapancsa pump plant was built, which was already designed for inland drainage. Its capacity was 3 m³/sec. It is the largest pumping station in the floodplain and delivers water to the Ferenc Canal. The inland drainage was completed between 1905 and 1910 (based on the plans of Szilárd Küzdényi). Of the 20,000 hectares, waters from almost 1,800 ha were pumped (BUZETZKY Gy. 2002). In 1914, it was 96 km of prime inland waterway.

In 1925 the pumping station at Hercegszántó was completed. Between 1925 and 1927 another 110 km of inland water channel was built under the leadership of Lajos Porgányi (IHRIG D. 1973).

Due to the agricultural nature of the landscape, the population has also started to grow. By the end of the 19th century, there were about 200 farms on the island with a total of 1,000 permanent inhabitants, by 1920 their number had tripled to six hundred with 3,000 inhabitants (KENESSEY B. 1931).

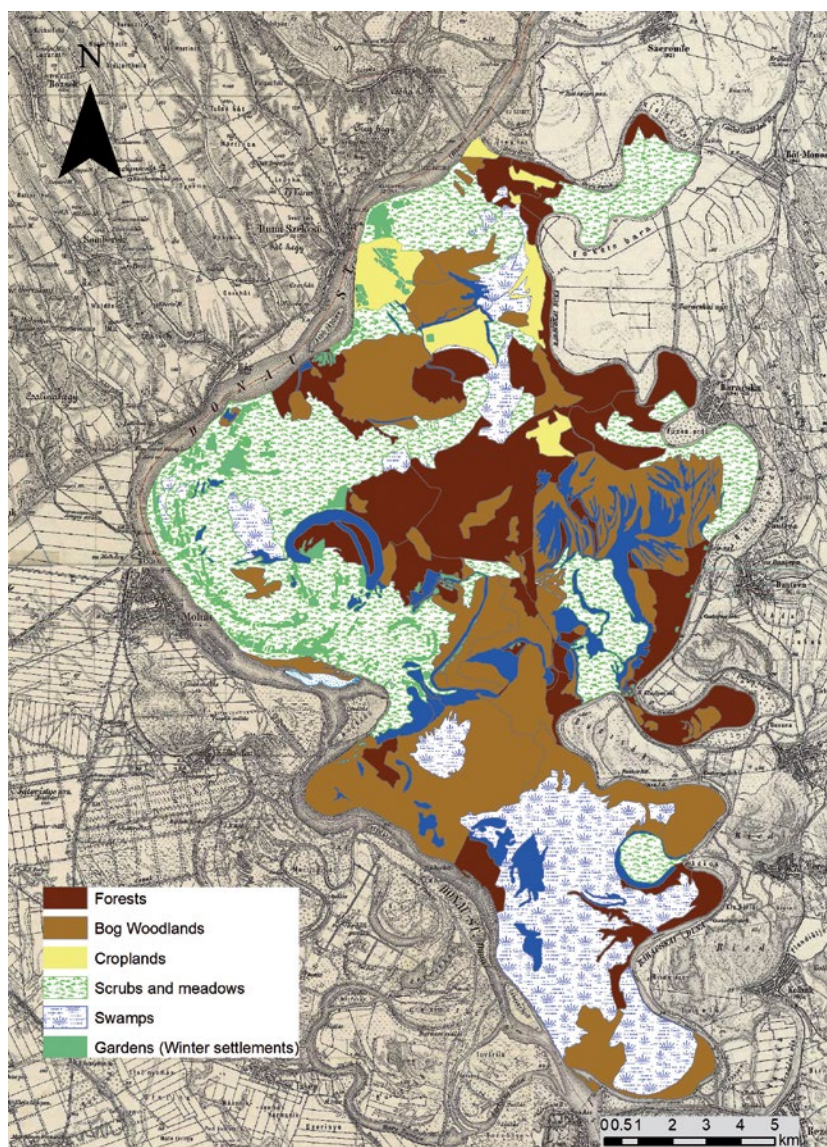


Figure 6 – Land cover map about Mohács Island around 1884 based on the Third Military Survey (self-made map, source: Mapire.eu).

Farmers living on the banks of the water were engaged in arable crop production, animal husbandry and fruit and vegetable production (FALUDI G. - NEBOJSZKI L. 2008). After the First World War, the southernmost part of the island (less than 10% of the total area) was transferred to the Serbian-Croatian-Slovenian Kingdom.

Much of the Bellye manor came to Yugoslavia after the First World War (ZÓKA P., 2013). Alien pine trees and invasive but economically valuable black locust (*Robinia pseudoacacia*) have already reached significant amounts of planted species (20 and 18 percent). Nevertheless, the area of the different oak types still exceeded the 60 percent at these riparian woods.

As a result of already begun constructions, the landscape pattern of the island has also undergone a radical change. The GIS interpretation (Table 1, Fig 7., Fig. 8) shows that by the 1950s agricultural land had grown from the previous 3% to 71%.

It revealed that the proportion of forests reduced from 44 percent to 20 percent. What is more, the wetlands almost disappeared until the middle of 20th century (only 3%).

Based on the GIS data, we can agree that the almost completely flood-prone landscape (BÍRÓ M. 2008) was taken over by man within a 150 years.

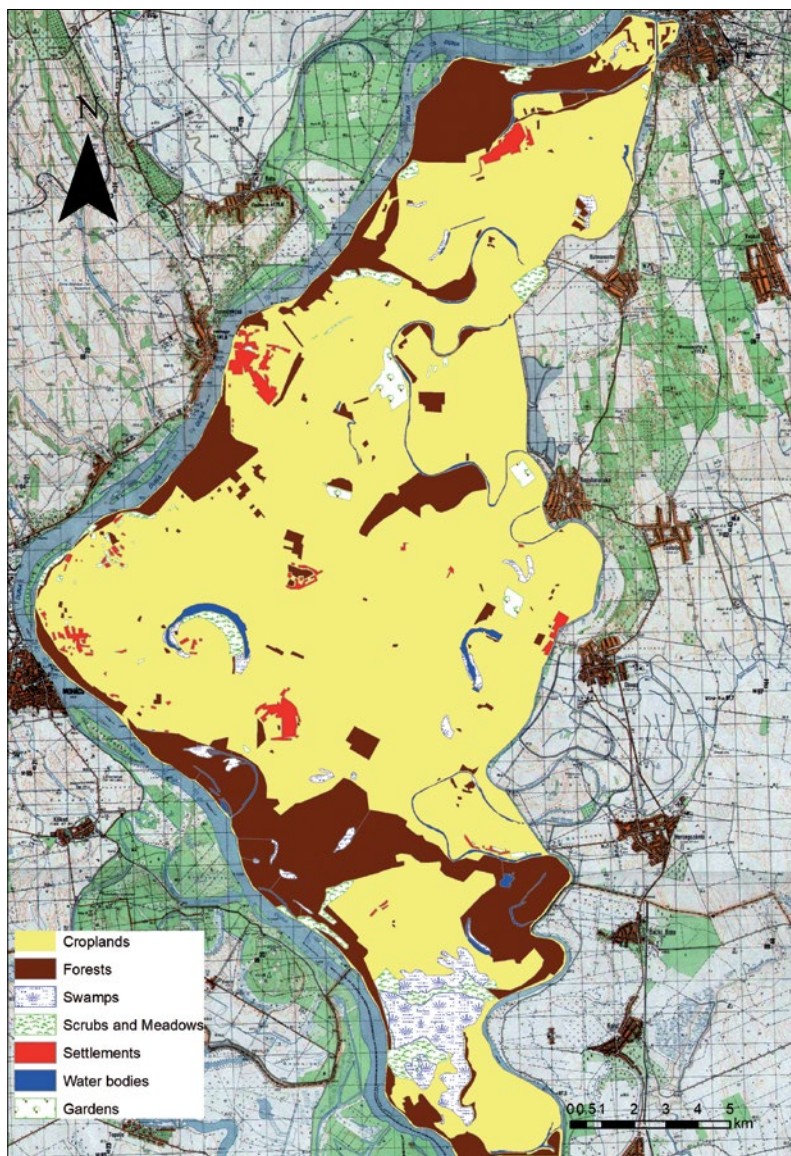


Figure 7 – Land cover map about Mohacs Island around 1952 based on a topographic map from that time (self-made map).

Table 1 – Proportion changes of the different landcover types

	Croplands	Forests	Bog woodlands	Swamps	Meadows and Scrubs	Settlements	Water bodies
1784	0.00%	58.93%	0.00%	32.73%	5.45%	0.13%	2.72%
1825	0.00%	44.07%	14.48%	11.77%	22.25%	4.71%	2.74%
1858	1.63%	45.42%	8.58%	16.53%	21.41%	3.96%	2.48%
1884	3.03%	19.59%	23.88%	15.71%	26.32%	2.77%	8.95%
1952	71.09%	19.74%	0.00%	3.33%	2.09%	1.58%	1.68%

In 1956, after more than sixty years, the island was flooded again by the ice flood, so in 1957 the dam level was raised by one meter compared to the latter flood level, the dams were reinforced and the pump capacity of the Karapanca was increased to 3.8 m³/sec (BUZETZKY Gy. 2002). In 1957, the embankments were raised everywhere around the island. Due to the urbanization under the socialist system, the isolated farmsteads and the related features of small-scale traditional farming were abolished.

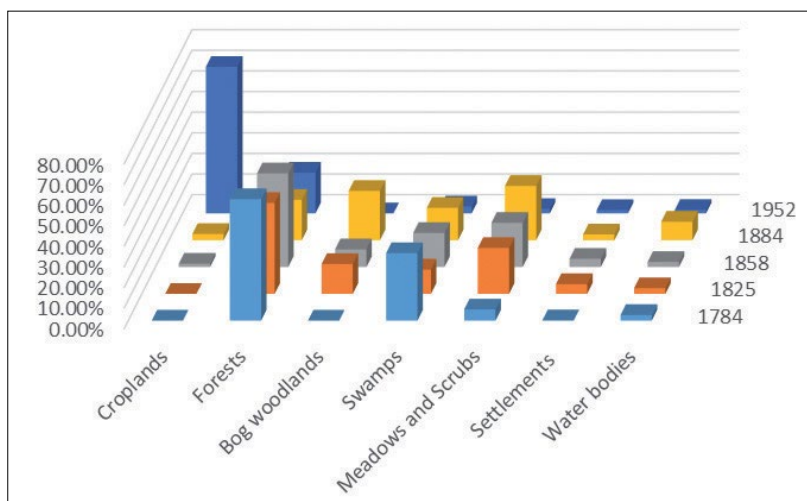


Figure 8 – Proportion of landcover types in the different times

CONCLUSIONS

Landscape transformations on Mohács Island continuously followed the river regulations and the inland water drainage works. Our research proved that from the initial works until the Danube mapping, only the area of the island got reduced. Due to the dam construction works during the 19th century, floods could reach the island less and less, although, by the end of the century it had become swampy. The original plans to convert the island into an agricultural land could not be realized at that time. Our maps and charts present these facts. At the beginning of the twentieth century, the landscape was transformed into agricultural as a result of inland drainage works. Arable agriculture became the most important farming form, and the oxbow lake fish management completely disappeared. In addition, our results point out that changes in the structure of settlements were adapted to changes in the landscape, therefore farmsteads were replaced by villages. In our work, the extent of the changes was collected and presented on maps and charts.

Furthermore, our study underlies later natural and social researches about Mohács Island. It helps to interpret landscape changes at local level and to evaluate GIS data from the past. These results may help to solve problems arising from the extreme watercourses of the Danube river system or from climate change, in particular, the reduction of groundwater level. What is more, we may also find an answer to the question that where an internal water damage can be expected due to a major flood or a rainfall event. The research is directly related to the most important local tasks of nature protection, especially the maintenance of wetlands. Our maps present the areas and lengths of different main types of habitats. Owing to the fact that hundreds of years have not passed since the works finished, the soil as a gene bank still contains the plant seeds of the original riparian habitats. Furthermore, our research may help to provide a theoretical basis for the review and conversion of agricultural activities on the island of Mohács (development of fruit production and fish farming). Finally, the GIS support of the historical and archaeological research of the Mohács Island is also one of the possible uses.

The results of the present study and the applied methodology during the research can contribute to the success of the Croatian-Hungarian environmental cooperation (BALI et al. 2015), which has significant importance for the protection of the Danube floodplains.

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SAŽETAK

Otok Mohač (ranije nazivan Margita) je riječni otok na Dunavu, smješten u južnom dijelu Panonske nizine u Mađarskoj, i djelomično se proteže u Hrvatsku. Regulacije rijeke u 19. stoljeću i povezani radovi odvodnje promijenili su obrazac krajolika i sustave poljoprivredne proizvodnje na riječnom otoku Mohač. Prve, druge i treće vojne geodetske karte, i manje poznate detaljne karte, takozvano mapiranje Dunava, korišteni su za rekonstrukciju krajolika u 18. i 19. stoljeću. Skenirane karte su digitalizirane i pretvorene u vektorsku kartu krajolika. Rezultati su uspoređeni s kartom krajolika na temelju topografske karte iz 1952. godine. Naša studija je upotpunjena etnografskim podacima.

U radu je dokazano da je udio močvarnih staništa i obalnih šuma uvelike smanjen (Tabela 1, slika 8). Istovremeno se sredinom 20. stoljeća omjer poljoprivrednog zemljišta povećao s 0 na 71 %. Međutim, taj proces nije bio linearan. Krajem 19. stoljeća otok je postao izrazito močvaran, što je vidljivo iz karte generirane na temelju treće vojne geodetske karte (slika 6, tabela, slika 8). Naše karte također prikazuju koliko je u kojem periodu bilo različitih obalnih staništa na otoku. Na temelju dobivenih rezultata se može zaključiti na kojim se kopnenim područjima mogu očekivati oštećenja uzrokovana vodom, a koja su područja najpogodnija za poljoprivrednu proizvodnju.