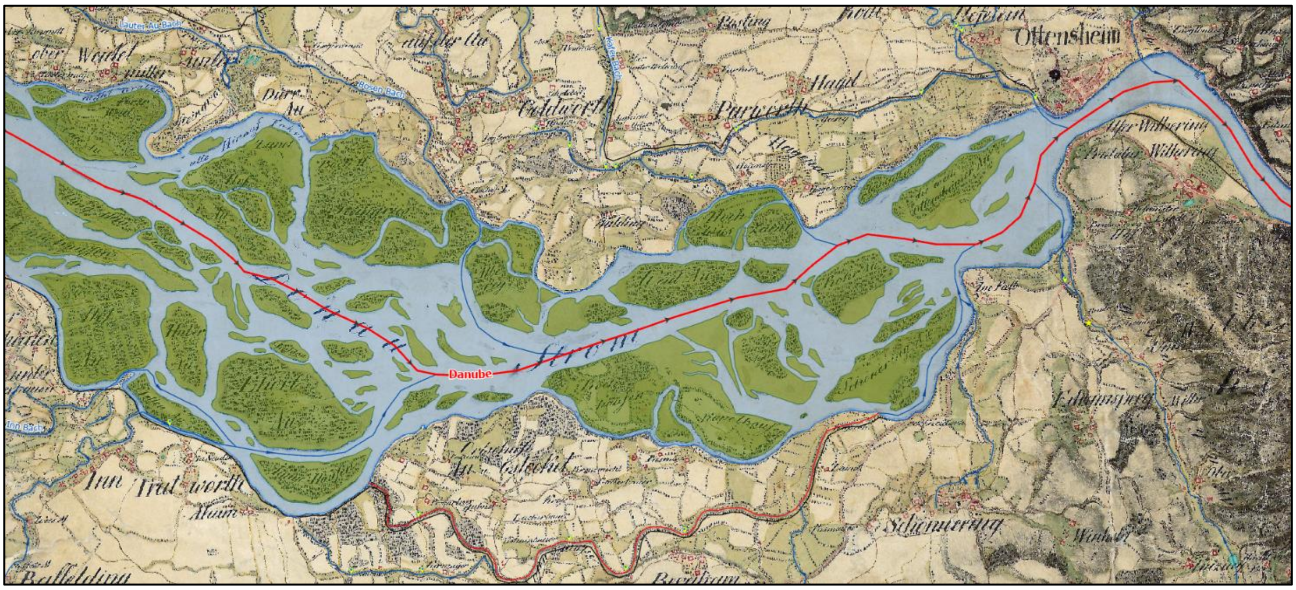

Digitalisation of historical hydrological maps

Pilot 2 - Wallachia

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15/06/2022	1	Final version

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TABLE OF ACRONYMS

AOI	Area Of Interest
MMU	Minimum Mapping Unit
EU	European Union
ETC	European Topic Centres
ERDF	European Regional Development Fund
IPA	Instrument for Pre-Accession Assistance
ENI	European Neighbourhood Instrument
GPC	Ground Control Point
WMTS	Web Map Tile Service
RMS	Root Mean Square
EU DEM	European Digital Elevation Model
MGI	Austrian Institute of Military Geography

1. INTRODUCTION

The overall objective with the digitalisation of the historical hydrological features is to support the Biodiversity Strategy 2030. The EU's biodiversity strategy for 2030 is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030, and contains specific actions and commitments [1]. Among them, the restoration of 25,000km of rivers through barrier removals is highlighted. So, point features such as dams, channels, barriers, etc. would become an important feature.

Besides, straightened rivers are ecologically less valuable, and it is also important to be able to measure how much rivers have been straightened.

This pilot may help to better understand the possibilities of developing quantitative measurements that allow for better "identification" of areas suitable for restoration. The document could be disseminated to different European Topic Centres (ETCs) and thematic experts to gather feedback and ideas on its potential for implementation.

The results of the pilot will be published on an online viewer and all the work that has been done is documented in this report.

2. SELECTION OF THE STUDY AREA (PILOT 2)

As mentioned in [2] within the Danube Transnational Programme, programme co-funded by European Union founds (European Regional Development Fund (ERDF), Instrument for Pre-Accession Assistance (IPA), European Neighbourhood Instrument (ENI)), and in particular the Danube Floodplain public project [3], the information regarding the Danube river former/historic floodplains was used to define the possible study areas or pilots [4] [5] [6], see Figure 1.

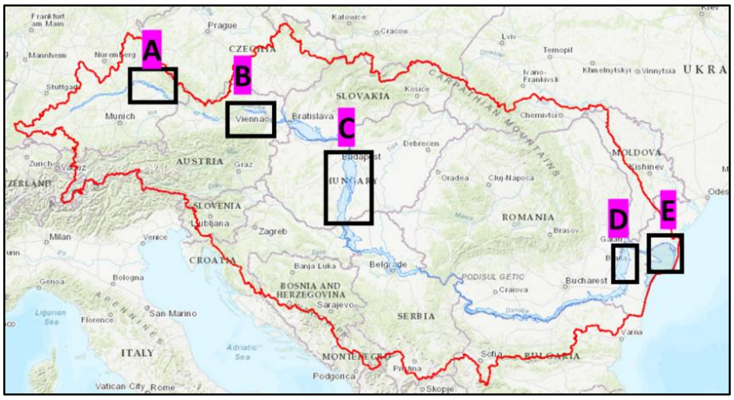


Figure 1. Possible pilot areas along the Danube river suggested by Tracasa Global.

Five possible study areas were defined along the Danube river, based on the surface covered by the floodplains. The main aspects of each of the possible study areas were gathered in a previous report [2].

First, the study area "B" was chosen as Pilot 1 since it covers both alpine and valley bottom areas, see Figure 1. Its digitalisation was finished on March 2022, and all the findings were gathered in a document [2].

Then, it was decided to move to another different area, and it was suggested to assess the possibility of digitalising the Delta area (the study area "E" in the figure above). For this aim, (1) the availability of the legend used, and (2) the accuracy of the historical map covering the area of interest (AOI) were checked among others.

2.1. Feasibility to digitalise study area "E"

This area is located in Romania, in the Biosphere Reserve of Delta Dunari, and covered approximately 4,000km^2, see Figure 2. Unlike the other pilots, it is located in a coastal area.

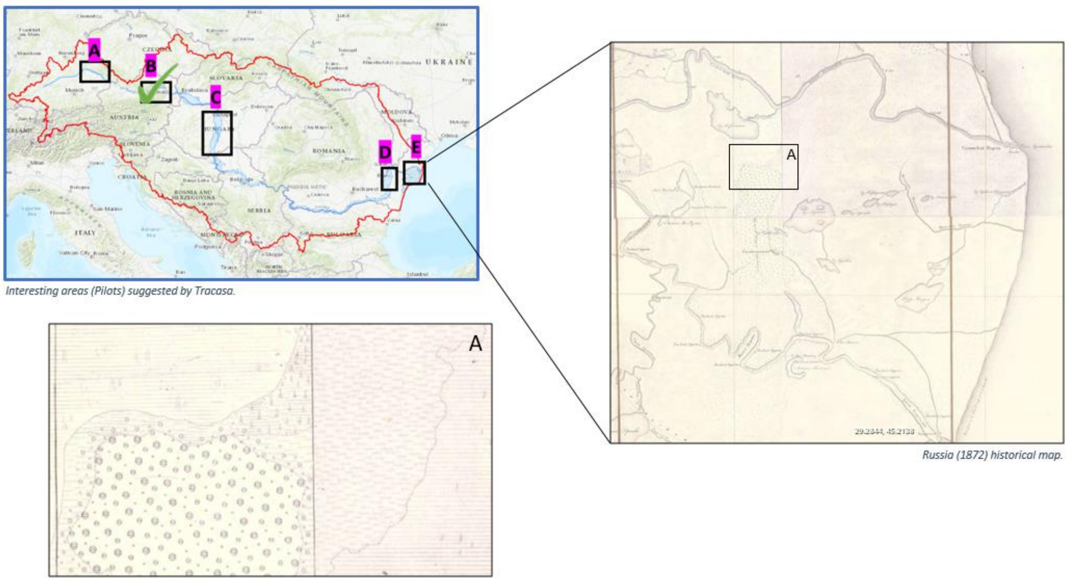


Figure 2. Location of Delta Dunari and the historical map appearance.

Historical map and its legend

This area is covered by Russia historical map (1872), and it was observed that it used a different symbology than the one used in Pilot 1. The legend was not available on the map website, and although finally it was possible to obtain it, it was found to be written in Russian (Cyrillic alphabet), see Figure 3.

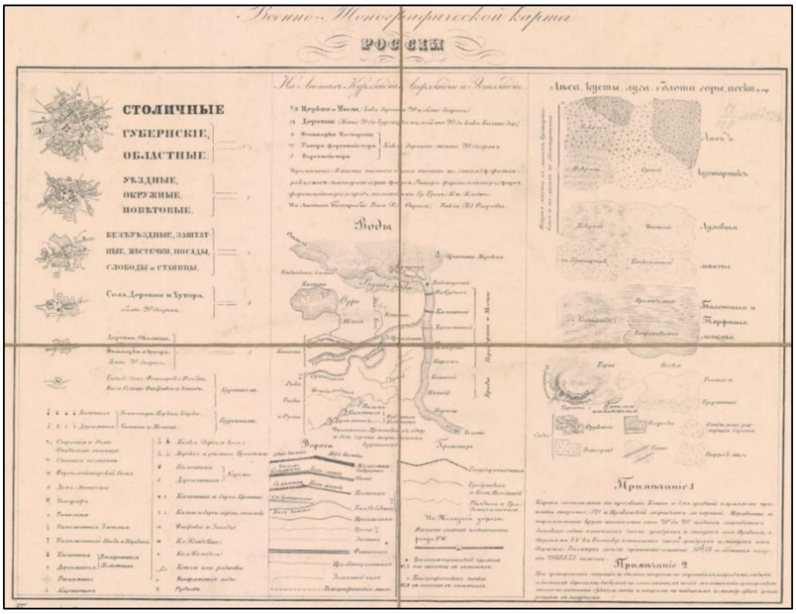


Figure 3. Legend of Russia (1872) historical map.

It was also observed that the positional accuracy of the map covering the Delta was very low. Errors up to 5 km were detected, see Figure 4. On the left side, the river (in dark blue), the water bodies (in light blue), and the coastline (in yellow) drawn over the historical map are shown. The same features over the ESRI World Imagery are presented on the right. Note that although the river polygon follows approximately the same trend or shape as the current one, it is displaced. Besides, it is observed that this displacement is non-systematic, *i.e.,* in some areas as the one shown on the top of the picture, the river polygon is displaced almost 5km mainly to the East, while the displacement observed in the other two cases shown is mainly to the southern part.

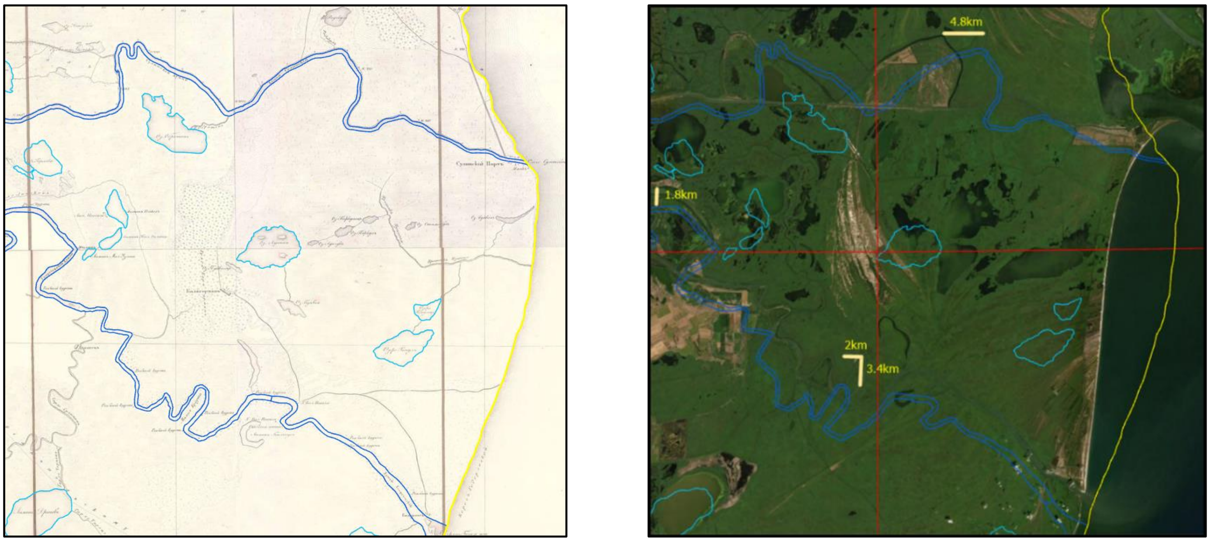


Figure 4. Positional errors detected over Russia (1872) historical map.

So, taking into account the mentioned problems, this option was discarded and instead, the area closest to the Delta was assessed.

2.2. Feasibility to digitalise study area “D”

After discarding the study area “E” to be used as Pilot 2, it was decided to move to study area “D”. This area is located in Romania, very close to Delta and it has a very different geomorphology compare to the Pilot 1. It is a flat area where a lot of lakes and wetlands or soft lands can be observed, see Figure 5.

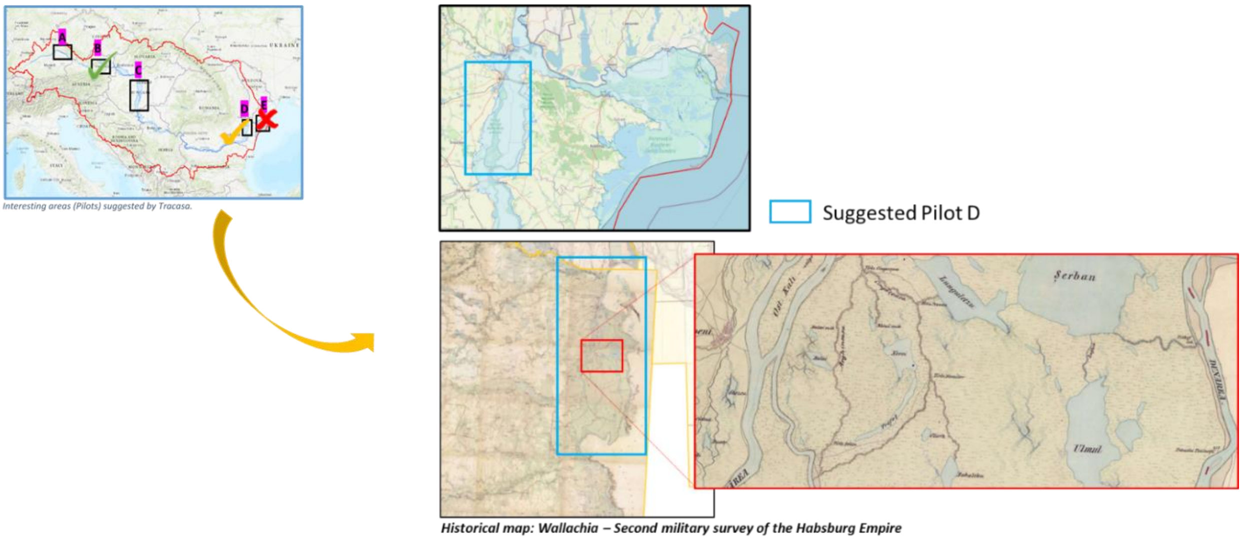


Figure 5. Location of study area “D” and the historical map appearance.

Historical map and its legend

The surveying organization of these map sheets was the Austrian Institute of Military Geography (MGI) [7], and as stated in [8], from 1827 the MGI used consistent symbols, totally of 245 classes. This legend was available on the map website [9] [10], and moreover, it corresponded to the same legend as the one used in Pilot 1.

Regarding the positional accuracy of the map, as stated in [8] and [11], positional errors up to 200-300m were observed, see Figure 6 and Figure 7. In the first figure, an urban area close to the Danube river is observed. Focusing on the main streets of the village it seems that the accuracy of the historical map in this area is quite good.

Figure 6. Analysis of the positional error of the historical map, urban area.

Figure 7 shows the positional errors observed in another area studied. In frame A, and frames B and C, horizontal and vertical positional errors are shown respectively. Note that the magnitude of the errors observed on one side or the other of the lake is very different. These errors should be taken with care since they correspond to natural surfaces that could have been modified over time. Besides, as stated in [8], "*most of the overall errors are due to the effect of the copy of the original sheets and the age, folding and drying of the paper sheets*".

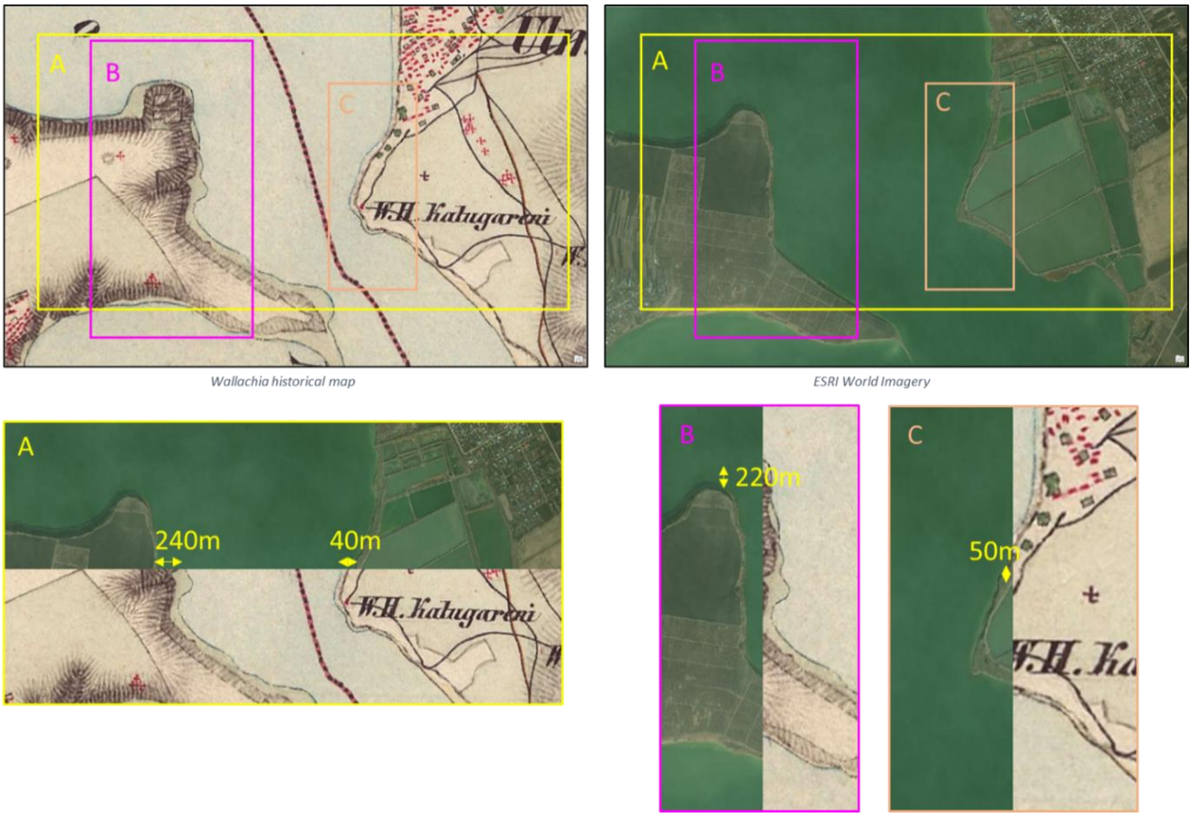


Figure 7. Analysis of the positional error of the historical map, natural area.

So, after checking the availability of the legend and the accuracy of the historical map, it was concluded that this option was suitable to be used as Pilot 2. Besides, it seemed to be an interesting area since features not observed in Pilot 1, *e.g.,* wetlands, were observed when assessing its feasibility.

3. PILOT 2

In this section, the historical map covering Pilot 2 and its characteristics are described more in depth.

3.1. Historical map Pilot 2

The map covering the study area "D" selected as Pilot 2, corresponds to Wallachia – Second military survey of the Habsburg Empire, see Figure 8. The red polygon indicates the general AOI that was initially drawn.

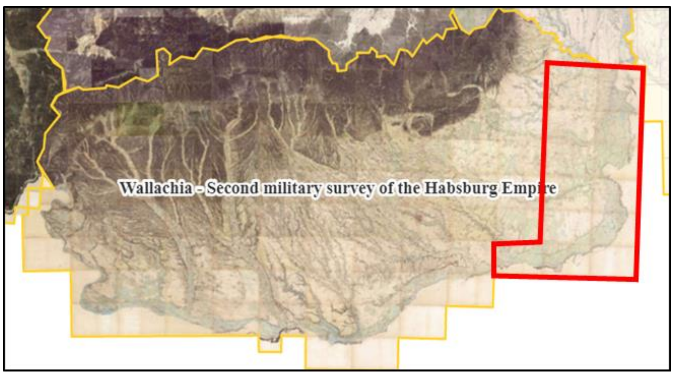


Figure 8. Wallachia – Second military survey of the Habsburg Empire historical map and the general AOI in red.

According to the information consulted [7] [8], these map sheets were surveyed between 1855 and 1859, see Figure 9, and although the usual scale of the Second Military Survey of the Habsburg Empire was 1: 28,800, because of the short time available for its creation, the scale of these maps was halved to 1: 57,600.

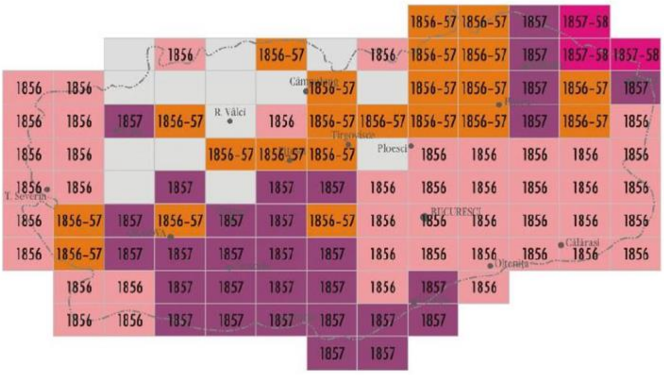


Figure 9. Years of the map sheets.

The Wallachia map was drawn in two versions, (1) the original one, Austrian version, and (2) the copied version for Romania, created on 1864 (available in a map viewer [12]), see Figure 10. The former is the one available in Arcanum website, so it is the one that it has been used.

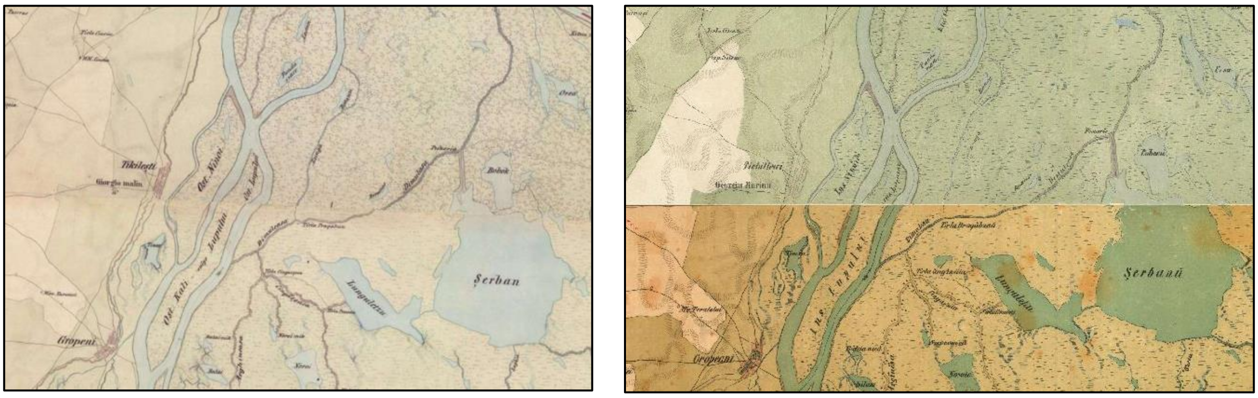


Figure 10. Wallachia historical map, (1) the original version one on the left, and (2) the copied version on the right.

The maps represent in detail the hydrography, the vegetation, settlements, routes, and borders among others, and the symbology used was similar to the maps of the second military survey [8].

Regarding the language, on the Austrian sheets the original Romanian toponyms in Cyrillic characters were transcribed into Latin ones, the other texts were in German. On the copied version, the Romanian toponyms are in the recently introduced Latin script, any other texts are in Romanian [8].

3.2. Pilot 2 AOI definition

Initially a general AOI was drawn, covering 26,352km^2, see Figure 11. Riparian zones layer available in [13] was used as a mask in order to select the most interesting areas. These Riparian zones represent transitional areas occurring between land and freshwater ecosystems, characterised by distinctive hydrology, soil and biotic conditions and strongly influenced by the stream water [14].

Based on both, Riparian zones layer and the historical map, the AOI of Pilot 2 was defined. Areas covered by Riparian zones layer but without information in the historical map were excluded, *e.g.,* the area in the northern part or all the small branches on the East side were excluded because of the lack of information of the historical map, see Figure 11.

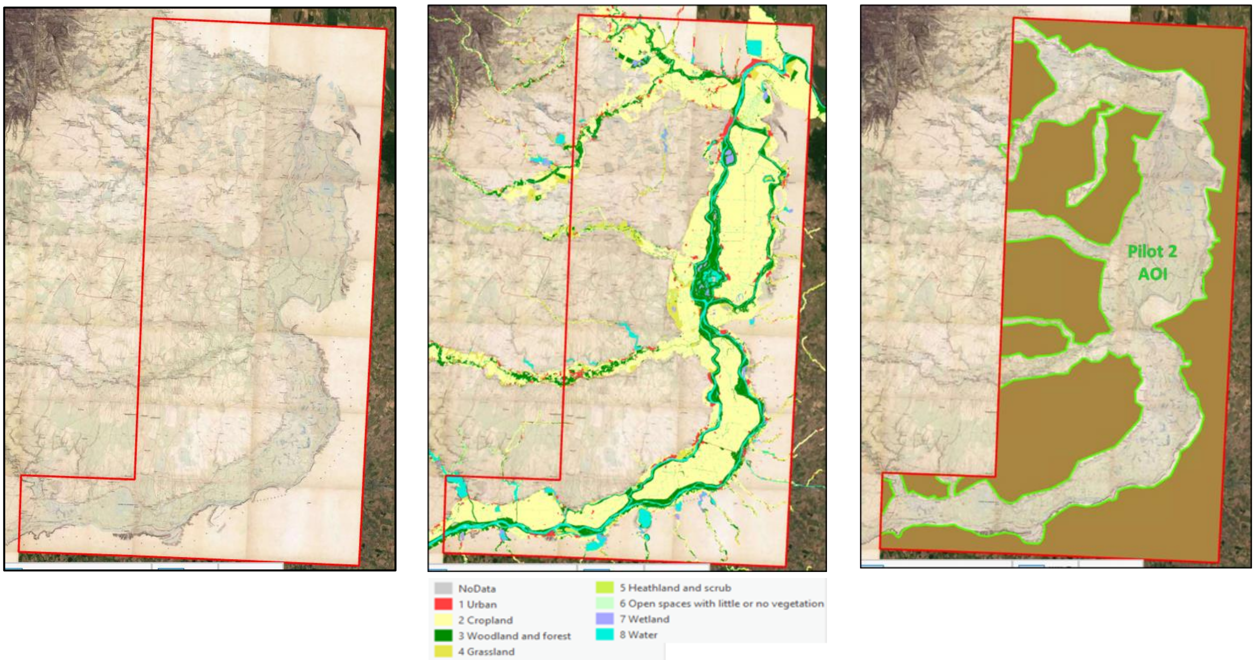


Figure 11. Definition of the Pilot 2 AOI. The general AOI in red over the Wallachia historical map (left), the Riparian zones layer (centre), and the Pilot 2 AOI in green (right).

Note also that the final Pilot 2 AOI, was not directly obtained using the Riparian zone as a mask. In addition to exclude areas without historical map information, other areas containing hydrological information were added. This extension of the AOI was carried out manually by photo interpretation, see Figure 12.

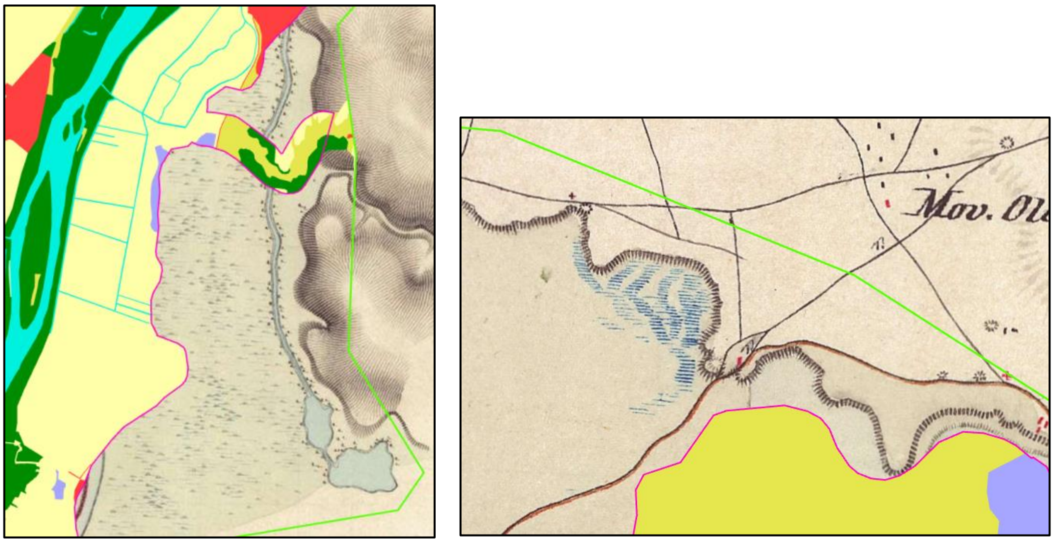


Figure 12. Some areas of the Pilot 2 AOI were manually added, the areas between the pink and green lines.

The final Pilot 2 AOI covers 10,795km^2.

4. HYDROLOGICAL FEATURE CLASSES

As a starting point, the same hydrological feature classes and attributes defined for Pilot 1 were taken into account. Twelve feature classes were defined: six polygon feature classes, three line feature classes and three point feature classes, see Figure 13. Note that the "_A", "_L", and "_p" endings were added to polygon, line and point feature classes respectively.

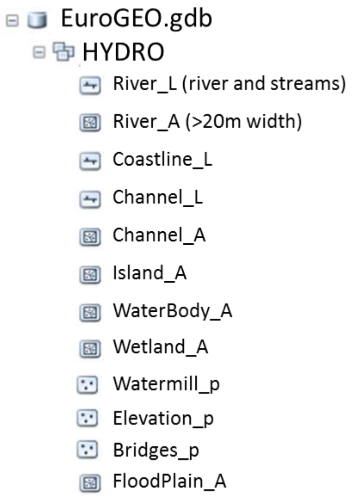


Figure 13. Structure of the ESRI File Geodatabase defined for Pilot 1.

In the case of Pilot 2, not all the feature classes defined for Pilot 1 were used. Moreover, a new feature class was added, "DryDitch_L", see also Section 6.1.6. The following tables summarizes the hydrological feature classes and attributes used for Pilot 2.

Polygon feature classes

Table 1. Polygon feature classes.

Polygon feature	Description	MMU
River_A	Streams and riverbanks or water edges.	
Island_A	Land area surrounded by water. It can be a lake or river island.	
Waterbody_A	Gathers different inland water bodies: - Natural lake: lakes, ponds, swamps, lagoons. - Artificial: reservoir (dam). - Oxbow lake: lake – former part of river course – created by erosion. - Watermill pond: water body used as a reservoir for a water-powered mill.	20m width / 400m²
Wetland_A	Peatbogs, cane growing areas, soft lands, marsh lands…	

The following table shows the attributes defined for the polygon feature classes. Note that there are some common fields and other specific ones, *i.e.,* for islands and waterbodies.

Table 2. Attribute table of the polygon feature classes.

Polygon feature	Attribute table fields	
For all of them	Map name (Source info)	*"Wallachia – Second military survey of the Habsburg Empire"**
	Year	*"1855-1859"**
	Digi_Author	*"Tracasa Global"**
	Digi_Year	*"2022"**
	Feature_name	If any, the name of the river, stream, lake,… is provided.
	Shape_Length	Automatically calculated
	Shape_Area	Automatically calculated
Island_A	Location	The location of the island. To choose among: Lake / River
	Lake_River_name	If known, the name of the river or lake on which the island is located is provided.
Waterbody_A	Type	To choose among: Natural lake / Artificial / Oxbow lake / Watermill pond
Wetland_A	Type	To choose among: Peatbog / Schilf growing areas / Soft land / Marsh land

* Text defined *by default* for this specific Pilot 2.

Line feature classes

Table 3. Line feature classes.

Line feature	Description	MMU
River_L	A naturally flowing watercourse. Represented by centre line of all streams and rivers.	50m length
DryDitch_L	Ditches where water can flow but are usually dry.	

Table 4. Attribute table of the line feature classes.

Line feature	Attribute table fields	
For all of them	Map name (Source info)	*"Wallachia – Second military survey of the Habsburg Empire"**
	Year	*"1855-1859"**
	Digi_Author	*"Tracasa Global"**
	Digi_Year	*"2022"**
	Feature_name	If any, the name of the river, stream, channel, coastline,… is provided.
	Shape_Length	Automatically calculated
River_L	Accuracy	To choose among: Clear / Diffuse

* Text defined *by default* for this specific Pilot 2.

Point feature classes

Table 5. Point feature classes.

Point feature	Description
Bridges_p	Different type of bridges that can be observed over the maps.
Watermill_p	Watermill points, associated with watermill ponds.

Table 6. Attribute table of the point feature classes.

Point feature	Attribute table fields	
For all of them	Map name (Source info)	*"Wallachia – Second military survey of the Habsburg Empire"**
	Year	*"1855-1859"**
	Digi_Author	*"Tracasa Global"**
	Digi_Year	*"2022"**

* Text defined *by default* for this specific Pilot 2.

5. DIGITALISATION RULES ESTABLISHED

5.1. Basic specification

- **EuroGEO_Pilot2_Wallachia.gdb** was created containing all the hydrological features defined in the previous section. Domains were created when needed, in order to facilitate the digitalisation process and avoid typo errors, *e.g.,* different waterbody types (natural lake, artificial, oxbow lake and watermill pond).
- The digitalisation scale was set on 1:5,000 – 1:20,000 in order to reach the MMU established.
- The projected WGS 1984 Web Mercator (auxiliary sphere) coordinate system was established, the same as the maps available through the Arcanum WMTS server.

5.2. Specific rules

All the specific rules defined for Pilot 1 were taken into account, and the following table summarizes all of them. Besides, new ones were added when working on Pilot 2, see Table 8.

Table 7. Specific rules used when digitalising both Pilot 1 and Pilot 2.

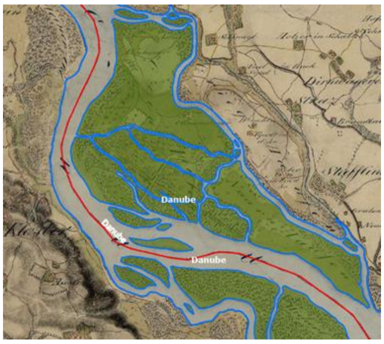
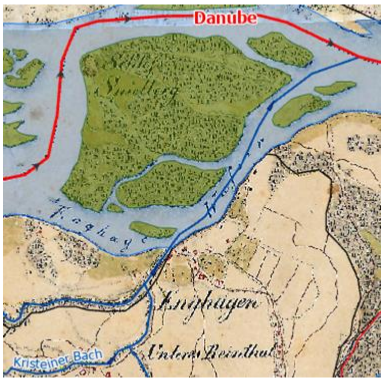
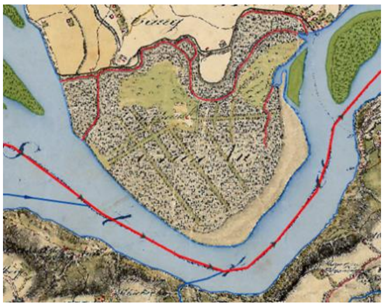
Rule	Description	Example
River polygons can contain gaps	River polygons could contain gaps, and these gaps corresponded to islands. In the case of branched rivers, all the connected branched rivers wider than 20m (established as a MMU) were considered.	
River unique centre lines	Each single river wider than 20m, was represented as polygon and also as line feature class. This line feature class represented the river centre line, and was symbolized with a line with an arrow indicating the direction of the flow. In the case of branched rivers, it was also defined a unique centre line, and this line could not overlapped with the islands.	
Stream lines connected with the main river line	The stream line was connected to the centre line of the main stream following the shortest way, the flow direction, and without overlapping the islands.	
Branched rivers representation	All the connected branched streams or rivers wider than 20m were considered and drawn as polygons. Those narrower than 20m, were also considered, and were drawn as lines. These lines were not connected with the centre line of the main stream since they correspond to the same river and did not contribute with an external water flow.	
Lakes centre lines	In cases where a stream flows to a lake, a centre line was also drawn in order to maintain a continuity.	

Table 8. Specific rules added for Pilot 2.

Rule	Description	Example
Dry ditches representation	Dry ditches were only represented as line feature class. Ditches of different sizes (width) were observed, but they were only represented as lines because they did not contain water.	

6. FINDINGS DURING THE DIGITALISATION PROCESS

In this section, all the findings found during the digitalisation process of Pilot 2 are described.

6.1.1. Complexity of maps

The complexity of different map sheets covering Pilot 2 was not high. Besides, the complexity among different map sheets was uniform, since the entire extent of the AOI is located over a flat area with big hydrological features (waterbodies, wetlands, etc.).

6.1.2. Quality of maps

It was observed that the quality of the different map sheets was good. Slight differences were observed between consecutive map sheets regarding the colour or symbology, but no differences were observed inside a single map sheet, see Figure 14.

Figure 14. Quality of different map sheets.

6.1.3. Accuracy of the maps

As previously mentioned, the error of the maps can also be high and in some areas can be as high as 200m as stated in [11], *i.e., "Accuracy of the Second Survey is surprisingly good in most parts of the Empire, the maximum error is cca. 200 meters"*, see also Section 2.2.

6.1.4. Lack of continuity between consecutive maps

In some areas, a lack of continuity between consecutive map sheets was also observed, see Figure 14. This may be due to the rectification errors mentioned in the previous point, and also due to the effect of the copy of the original sheets and the age, folding and drying of the paper sheets mentioned in Section 2.2.

6.1.5. High level of detail of the historical maps

Due to the high level of detail that the maps show, it has been possible to identify the name of many features (*e.g.,* rivers, lakes, streams) and include them in the geodatabase. Besides, in cases were the name was not clear enough, available basemaps have also been searched in order to get or verify the name.

6.1.6. Dry ditches, the new hydrological feature class

When digitalising the historical map, a new symbology not previously observed in Pilot 1 was detected, see the areas indicated with a yellow circle in Figure 16. According to the legends consulted, they correspond to “Dry ditches” and “Water ditches” or “Streams”, see Figure 16. The ditch in Figure 15B contains water so it was digitalised as “River_L” feature class while the others were drawn as “DryDitch_L”.

Figure 15. The new hydrological feature class observed in Pilot 2.

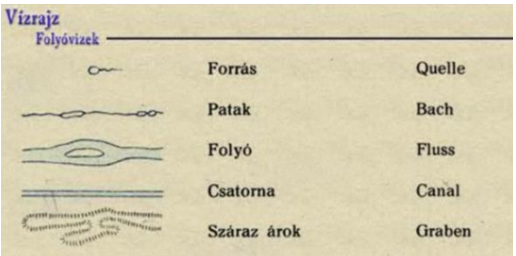
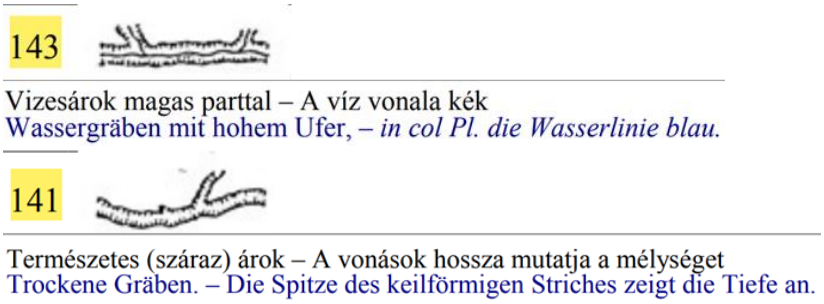
Legend (v1)	
	“Graben” means ditches in German.
Legend (v2)	
	Translation: 143: water ditches with high bank, waterline in blue. 141: Dry ditches, the top of the wedge-shaped line indicates the depth.

Figure 16. Legends checked in order to define the new feature class.

The following figures show some examples of the digitalised dry ditches (yellow lines). It was observed that when comparing with the ESRI World Imagery, in some cases these dry ditches lines fit quite well with the water-spots that are currently visible, see Figure 17.

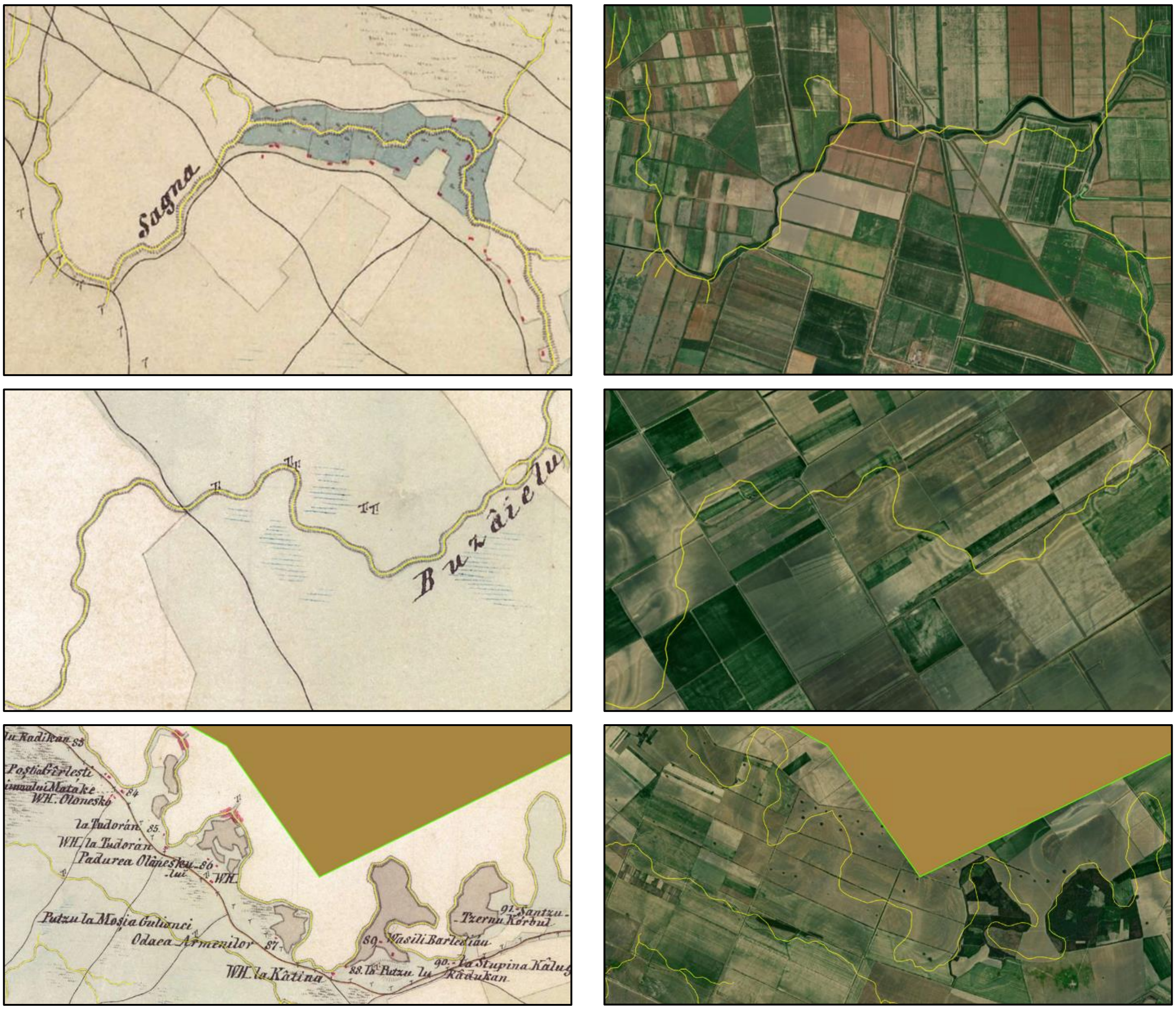


Figure 17. Dry ditches digitalised over the historical map in yellow and the same lines over the current optical imagery.

On the contrary, in other cases or areas, these dry ditches do not follow the same trend than the water-spots observed over the optical imagery, and it seems that they were drawn randomly, see Figure 18.

Figure 18. Area where it seems that the dry ditches were randomly drawn.

6.1.7. Wetlands

Two types of wetlands were distinguished, (1) Marsh lands, and (2) Soft lands. The first ones were mainly located close to the different water surfaces, and were represented by blue zigzag strokes. The second ones were represented by fine blue lines, and with or without vegetation, see Figure 19. At the top, the original historical map is shown while at the bottom, the same area is overlapped by the hydrological features that have been digitalised.

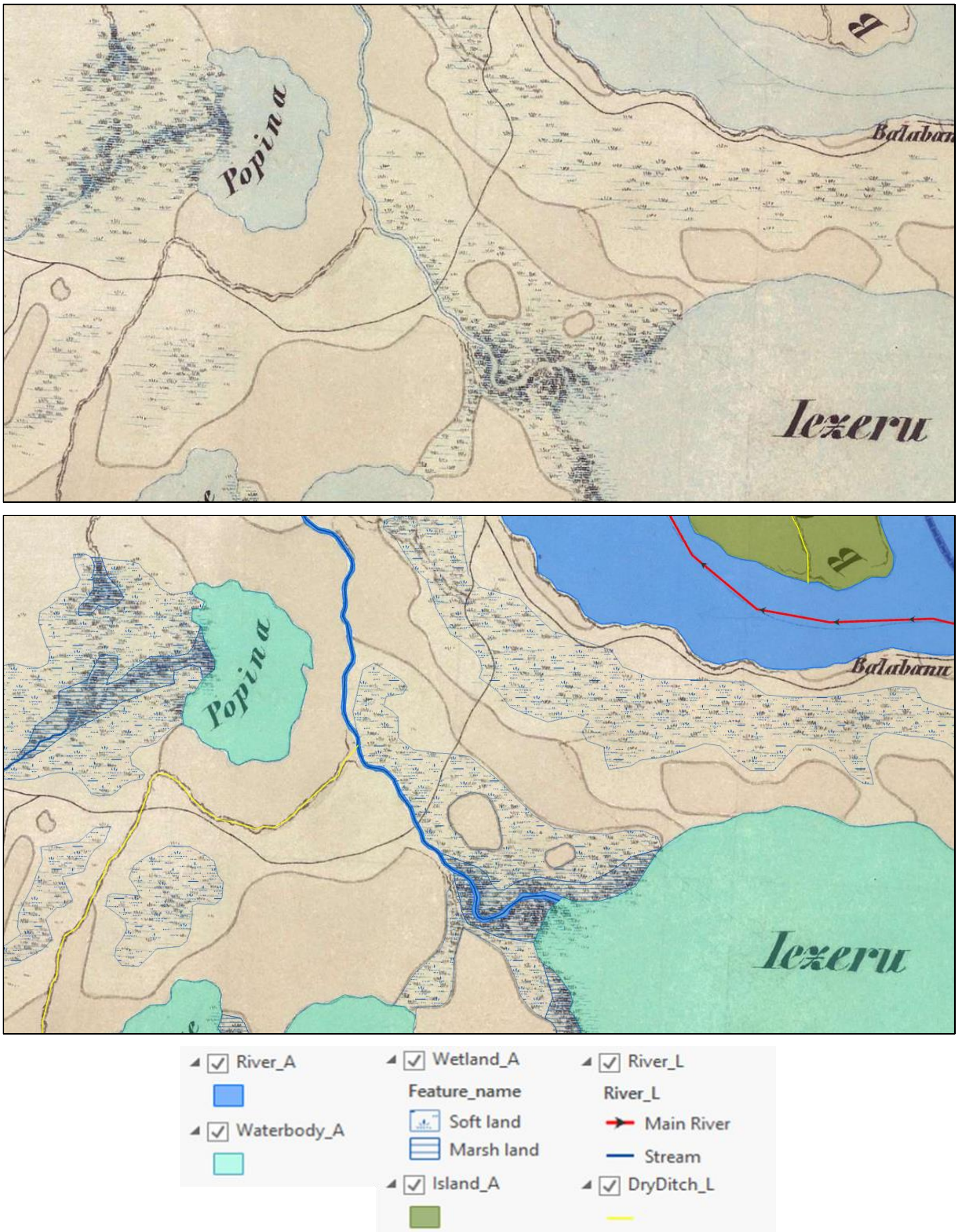


Figure 19. Different types of wetlands observed.

7. DIGITALISATION SUMMARY AND ANALYSIS OF THE RESULTS

7.1. Summary

The digitalisation rate was quite uniform due to (1) the learning curve was done with the previous case study (Pilot 1), (2) the legend was known, and (3) in general all the map sheets covering Pilot 2 had similar characteristics, *i.e.,* all of them corresponded to a flat region, same hydrological features (rivers, wetlands, dry ditches…) could be observed among different sheets.

Besides, unlike in Pilot 1, most of the hydrological features of Pilot 2 were so big that in many cases it was possible to digitalise using a smaller production scale than the one initially fixed.

In general this area, due to all the reasons explained above, has turned out to be a less complicated area to digitalise, and proof of this is that an average of **10 hours/1,000 km²** has been obtained, three times less than for Pilot 1.

7.2. Analysis of the results

Analysing the results, two aspects were highlighted: (1) the change of some rivers has been observed, *i.e.,* some sections of some rivers have been straightened, and (2) the disappearance of waterbodies and wetlands.

In order to complete the analysis of the results, a cross comparison between the polygon hydrological features digitalised and the riparian zones was carried out. This analysis gives an idea of the changes of Land Cover / Land Use (LC/LU) that have occurred over the years.

7.2.1. Straightened rivers

In the following figures, some examples of the straightened rivers are shown. They correspond to different locations over the Pilot 2. The pink point in the data frame on the right side of each figure indicates each location. The picture on the left and centre of each figure show the historical map and ESRI World Imagery respectively. The red line and blue polygon over ESRI World Imagery correspond to rivers digitalised over the historical map, and gives an idea of how much the river has been straightened.

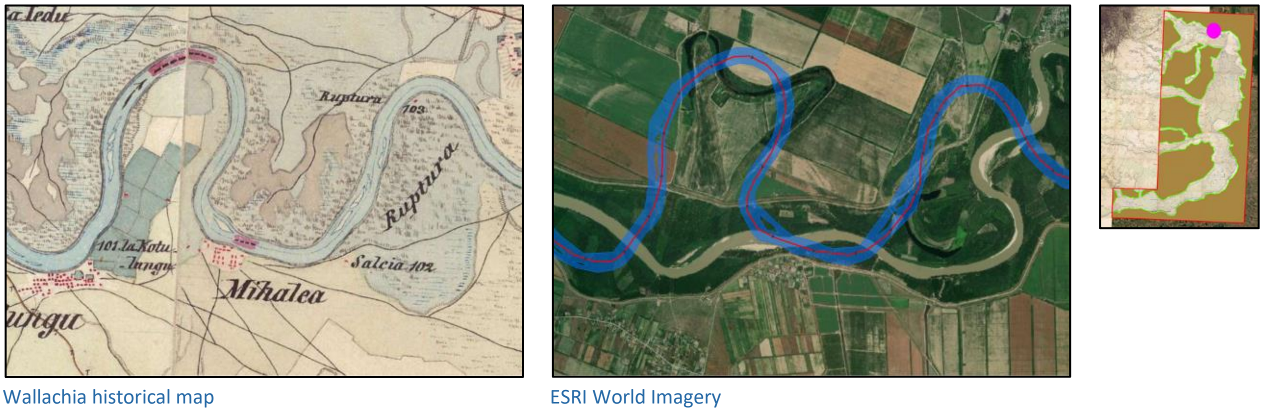
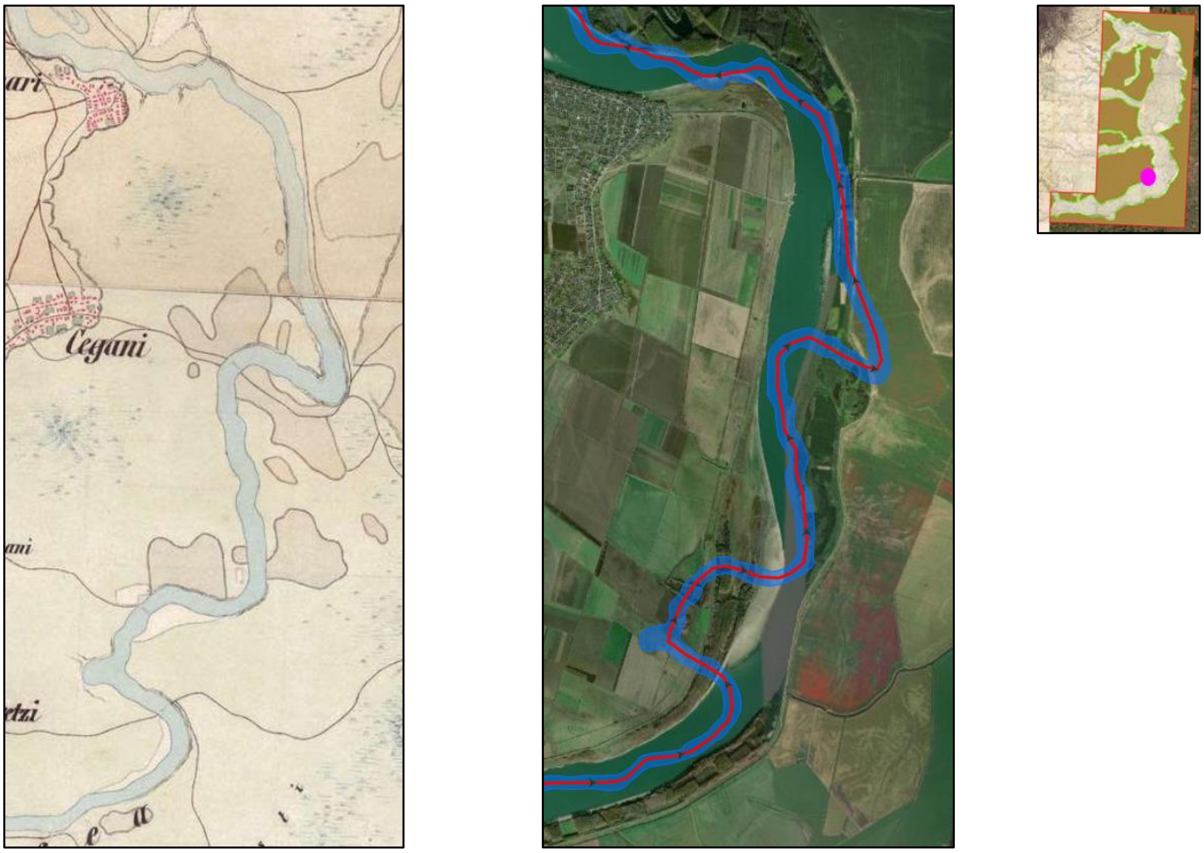


Figure 20. Straightened river section, example 1 (Siretu river).

Wallachia historical map ESRI World Imagery

Figure 21. Straightened river section, example 2 (Buzâu river).

The example shown in Figure 21 corresponds to the most extreme case observed in Pilot 2. It can be clearly observed how the Buzâu river has been straightened.

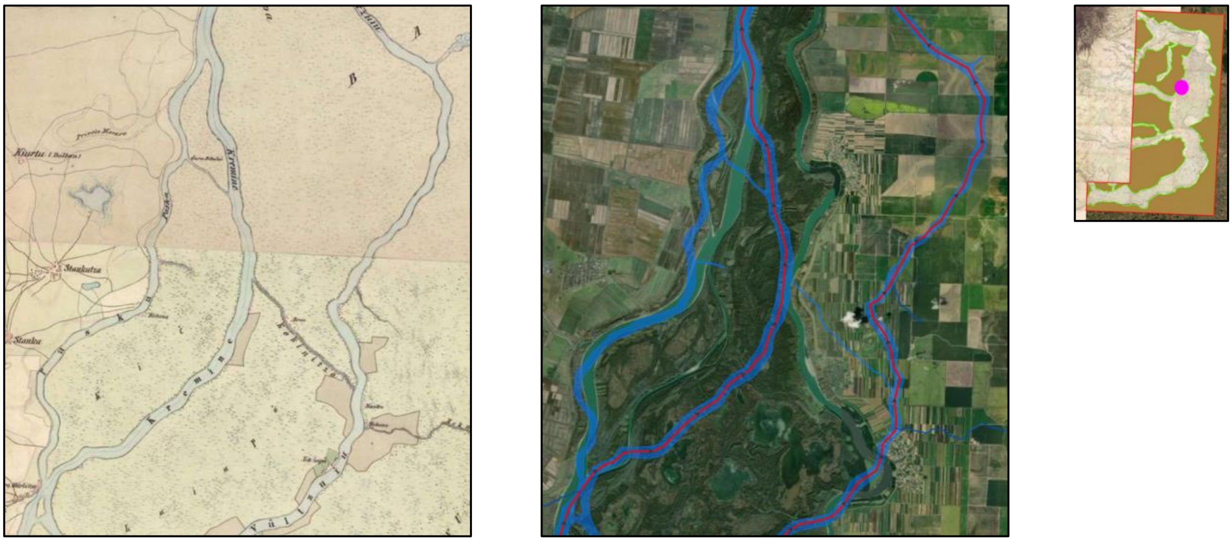


Wallachia historical map ESRI World Imagery

Figure 22. Straightened river section, example 3 (Borcea river).

The example shown in Figure 22, corresponds to another case that has been observed in Pilot 2. It can be seen how the Borcea river has been straightened in this part of the river.

Finally, in this area where the Danube flows, a lot of differences can be observed, see Figure 23. The water flows have changed over this area, *e.g.,* the branch on the right side currently does not exist.



Wallachia historical map

ESRI World Imagery

Figure 23. Straightened river section, example 4 (Danube river).

7.2.2. Waterbodies and wetlands

It was realised that most of the waterbodies and wetlands have dried up. As stated in [15], it is estimated that since 1900, 64% of the wetlands on our planet have disappeared victims of urban, agricultural and industrial development, overexploitation of water resources, pollution and the construction of dams. Figure 24 shows how different water surfaces have evolved over time in the studied area.

Hydrological features digitalised over **Wallachia historical map** (1855-1859)

Hydrological features contained in the **Riparian zones** layer (reference year 2018)

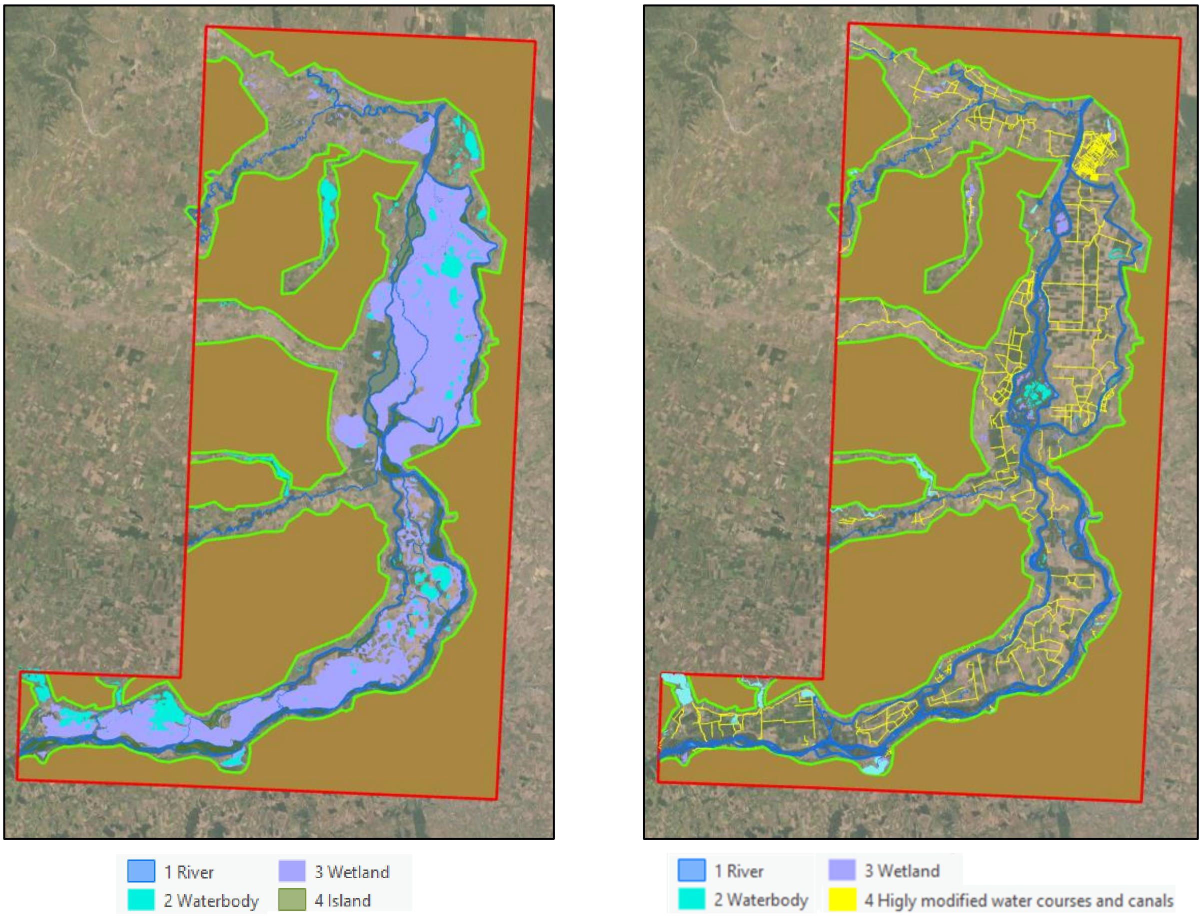


Figure 24. Evolution of different water surfaces over time, Pilot 2.

In the figure above, it is clearly observed that the wetlands and waterbodies have dried up. Table 9 shows the numeric values of the reduction observed.

Table 9. Statistics of the reduction observed for each hydrological feature.

Hydrological feature	Digitalised (1855-1859) (km²)	Riparian zones (Ref. 2018) (km²)	% of reduction in terms of surface
River	637.10	529.83	16.84
Waterbody	547.99	194.84	64.44
Wetland	3,369.59	123.44	96.33
Island	330.62	-	-
Channel	-	75.12	-

The reduction of the islands and channels has not been calculated since the Riparian zones layer do not contain an island category and no channels were observed during the digitalisation process. Regarding the other features, the most pronounced reduction is observed for wetlands (96.33%) followed by the waterbodies (50.74%). The river surfaces have suffered a less pronounced reduction (16.84%), and part of its reduction could be due to its straightening process.

Figure 25 shows an example of how Iezero lake has been drying up over time due to agricultural development in this area. The pictures in the first row show the Iezero lake over the historical map, current imagery, and the lake's location (overview data frame). In the second row, the evolution of the lake is shown. These images correspond to the Google Earth ones.

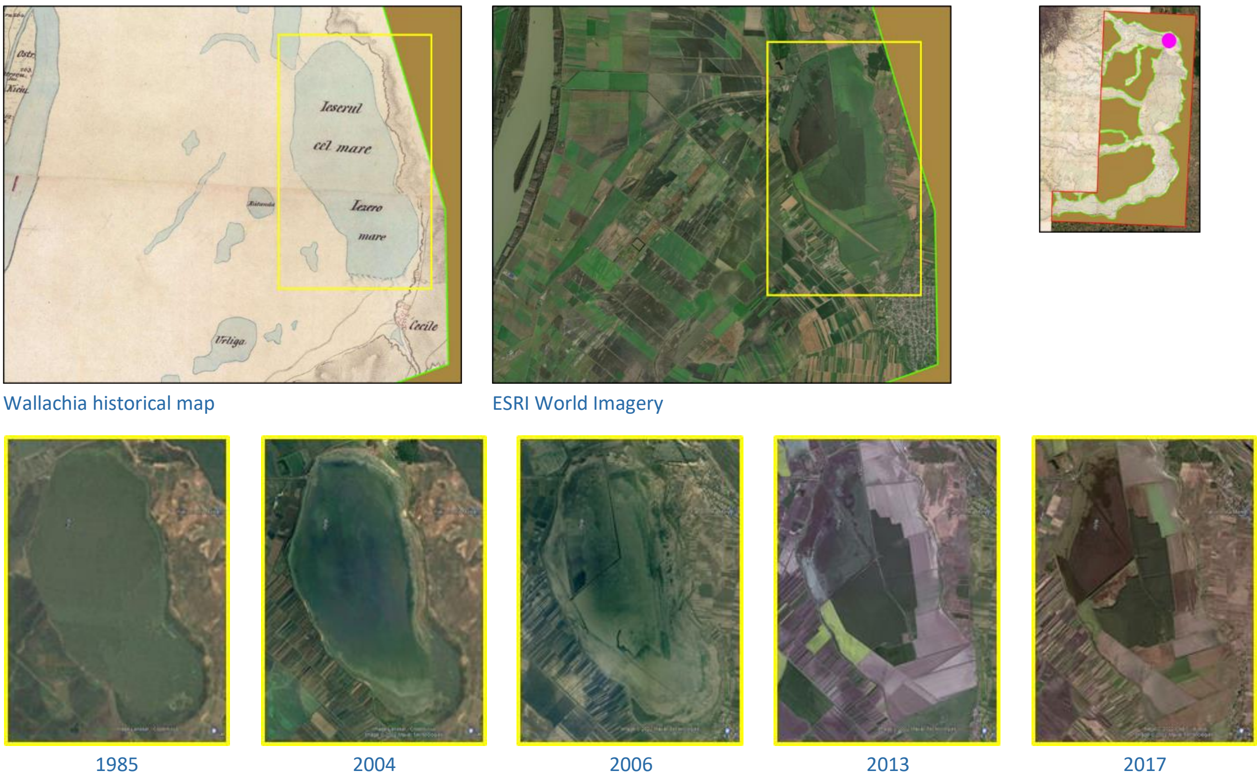


Figure 25. Drying up of Iezero lake (Source: Google Earth).

In the following example, the Serban lake is presented. There is no trace of the lake in the image of 1985 and there are no previous images available in google earth, however, it is observed that the area where the lake was located corresponds to a lower area according to EU DEM (European Digital Elevation Model), see Figure 26. The light blue lines over the EU DEM represent the waterbodies digitalised from the historical map.

Wallachia historical map ESRI World Imagery EU DEM

Figure 26. Evolution of Serban lake.

7.2.3. Cross comparison (Digitalised features *vs.* Riparian zones)

In order to complete the analysis of the results obtained, a cross comparison was carried out. For this aim, the digitalised hydrological features (river, waterbody, wetland, and island polygons) were compared with the current categories of the Riparian zones layer, see Figure 27.

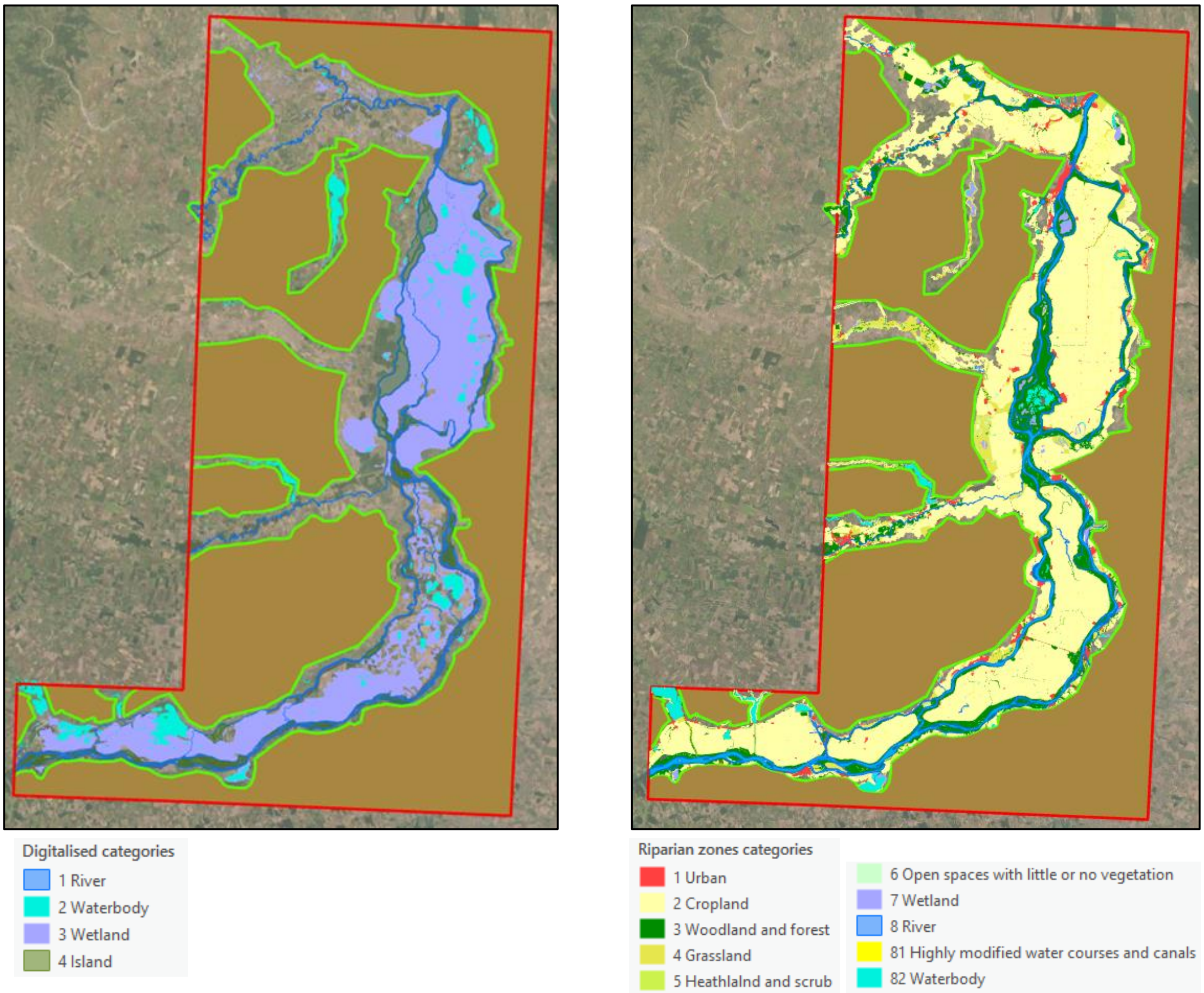


Figure 27. Hydrological features digitalised and the Riparian zones categories with whom it crosses.

Following, the results of the cross comparison are shown in a tabular format, see Table 10 and Table 11. The first table shows the results in square kilometers while in the second one, the results are shown in percentage (%) values with respect to the total of each digitalised feature. The most relevant results are highlighted in blue.

Table 10. Cross comparison results (Digitalised *vs.* Riparian zones categories), in terms of area (km²).

Area (km²)		Digitalised hydrological features (polygons)					TOTAL
		No Data	Island	River	Waterbody	Wetland	
Riparian zones categories	*No Data*	-	1.36	5.51	46.93	41.41	**95.20**
	Channel	41.05	0.34	1.05	4.98	27.73	**75.15**
	Cropland	2,782.28	41.25	69.25	348.08	2,556.59	**5,797.45**
	Grassland	422.00	14.40	21.27	21.73	58.58	**537.98**
	Heathland and scrub	1.71	0.34	0.52	0.11	2.15	**4.82**
	Open spaces with little/no vegetation	29.37	4.11	10.64	0.53	8.93	**53.58**
	River	140.78	50.50	250.83	5.03	99.67	**546.82**
	Urban	255.67	1.66	9.83	2.86	28.67	**298.70**
	Waterbody	68.16	4.59	5.83	73.64	45.00	**197.21**
	Wetland	41.76	25.00	5.15	25.73	47.41	**145.05**
	Woodland/forest	576.41	187.07	257.24	18.36	453.44	**1,492.52**
TOTAL		**4,359.19**	**330.62**	**637.10**	**547.99**	**3,369.59**	**9,244.49**

Table 11. Cross comparison results (Digitalised *vs.* Riparian zones categories), in terms of % values.

		Digitalised hydrological features (polygons)					TOTAL
		No Data	Island	River	Waterbody	Wetland	
Riparian zones categories	*No Data*	-	0.41%	0.86%	8.56%	1.23%	**1.03%**
	Channel	0.94%	0.10%	0.16%	0.91%	0.82%	**0.81%**
	Cropland	63.83%	12.48%	10.87%	63.52%	75.87%	**62.71%**
	Grassland	9.68%	4.36%	3.34%	3.96%	1.74%	**5.82%**
	Heathland and scrub	0.04%	0.10%	0.08%	0.02%	0.06%	**0.05%**
	Open spaces with little/no vegetation	0.67%	1.24%	1.67%	0.10%	0.27%	**0.58%**
	River	3.23%	15.27%	39.37%	0.92%	2.96%	**5.92%**
	Urban	5.87%	0.50%	1.54%	0.52%	0.85%	**3.23%**
	Waterbody	1.56%	1.39%	0.91%	13.44%	1.34%	**2.13%**
	Wetland	0.96%	7.56%	0.81%	4.70%	1.41%	**1.57%**
	Woodland/forest	13.22%	56.58%	40.38%	3.35%	13.46%	**16.14%**
TOTAL		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

No data categories derive from: (1) areas corresponding to one of the Riparian zone categories and with no information in the digitalised layers (because they do not correspond to any of the hydrological features), or (2) digitalised areas outside Riparian areas (because some areas of the Pilot 2 AOI were manually added, see Figure 12).

Approximately 28.67km^2 of the current *Urban* areas were occupied by wetlands in the past (10%). Considering all the digitalised hydrological features (island, river, waterbody and wetland) located over urban areas, this percentage rises to 14%.

Most of the digitalised River polygons correspond to *River* (39.37%) and *Woodland/forest* (40.38%) categories of the current Riparian zones layer, and these *Woodland/forest* areas are located very close to the river flows, see Figure 28. Black lined polygons correspond to the digitalised rivers and the Riparian zones layer is shown as the background image.

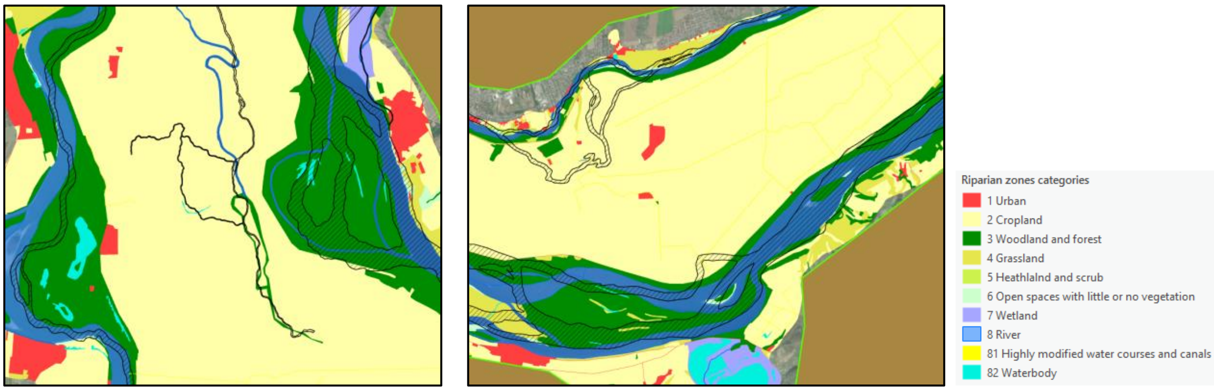


Figure 28. Digitalised river polygons (black lined ones) together with the Riparian zones layer.

The digitalised Island polygons follow the same trend than the rivers. Most of them fall over *Woodland/forest* (56.58%) category, and to a lesser percent to the *River* (15.27%) category. These islands can also be observed in Figure 28, they correspond to the areas located inside the river polygons.

Regarding the Waterbody polygons, most of them fall over *Cropland* (63.52%), see Figure 29A. Only 13.44% of the waterbody extent digitalised remains as *Waterbody* according to the Riparian zones layer, Figure 29B and the 8.56% of the waterbody extent was digitalised outside the Riparian zone extent, Figure 29C. As in the previous case, black lined polygons correspond to the digitalised islands and the Riparian zones layer is shown as the background image.

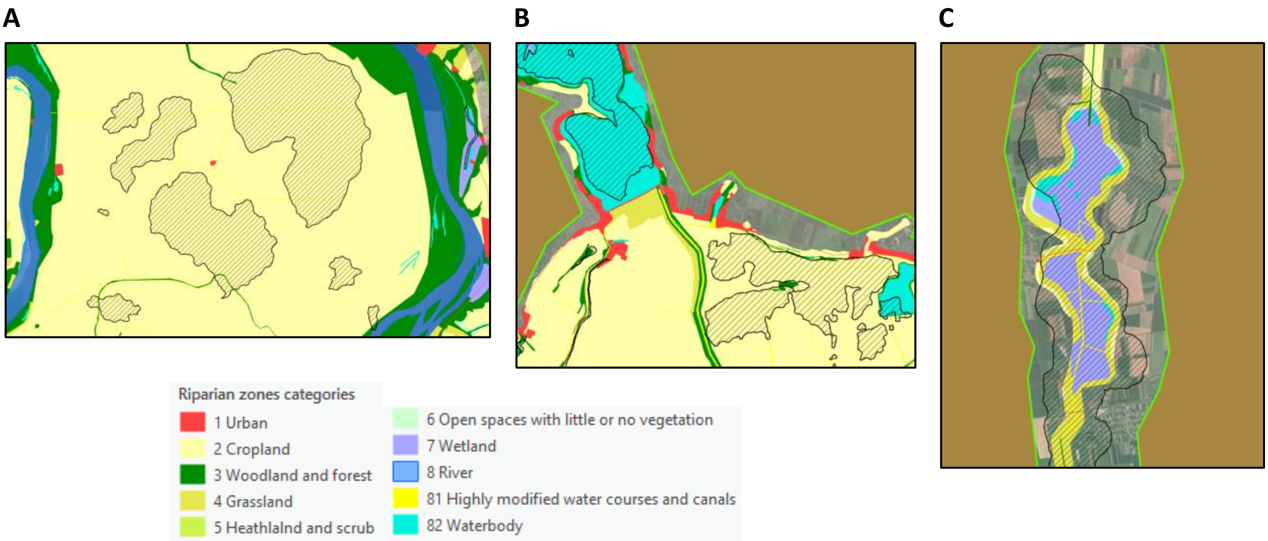


Figure 29. Digitalised waterbody polygons (black lined ones) together with the Riparian zones layer.

Finally, it was observed that the 75.87% of the Wetland polygons fall over *Cropland* category, and to a lesser percent to the *Woodland and forest* (13.46%) one.

These results were expected since according to the Riparian zones layer, 62.71% of the area covered by Pilot 2 corresponds to *Cropland* category, see Table 10 and Table 11. So, it can be concluded that the main reason for the disappearance of waterbodies and wetlands in this area was due to agricultural development.

Although the positional error of the historical map itself could be over- or under- estimating some of the results, this study reveals the high changes that can occur in hydrological features over time.

8. MAP VIEWER CREATION

In order to show all the hydrological features that were digitalised, a map viewer mock-up was developed.

Link to the map viewer:

https://portal.discomap.eea.europa.eu/arcgis/apps/webappviewer/index.html?id=a24efd2ad4694e1aa7fba6f10e30e8f9

9. DELIVERABLES

Together with this report, the .GDB is also provided. The link to the created map viewer is indicated in the previous section.

[1] https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en
[2] Digitalisation of historical hydrological maps. Report created by Tracasa Global. May 2022.
[3] https://www.interreg-danube.eu/approved-projects/danube-floodplain
[4] http://www.geo.u-szeged.hu/dfgis/
[5] https://www.interreg-danube.eu/uploads/media/approved_project_output/0001/48/431d3fbc4554bb9025a8ecef93769c2f503beee8.pdf
[6] https://www.interreg-danube.eu/uploads/media/approved_project_output/0001/48/b82111f67b5b38bfd14333370bc19c488c4167d1.pdf
[7] https://icaci.org/files/documents/ICC_proceedings/ICC2015/papers/18/fullpaper/T18-696_1428396969.pdf
[8] http://charta1864.gis-it.ro/essay.pdf

[9] https://www.arcanum.com/media/uploads/mapire/legend/secondsurvey1.pdf
[10] https://www.arcanum.com/media/uploads/mapire/legend/secondsurvey2.pdf
[11] Timár, Gábor & Biszak, Sándor & Székely, Balázs & Molnár, Gábor. (2011). Digitized Maps of the Habsburg Military Surveys – Overview of the Project of ARCANUM Ltd. (Hungary). DOI: 10.1007/978-3-642-12733-5_14.
[12] http://charta1864.gis-it.ro/charta.html
[13] https://land.copernicus.eu/local/riparian-zones/riparian-zones-2018?tab=download
[14] https://land.copernicus.eu/local/riparian-zones
[15] https://www.wwf.es/nuestro_trabajo/agua/humedales/