Hydrological and morphological changes of the Danube River between Giurgiu and Oltenita cities (Romania)

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Hydrological and morphological changes of the Danube River between Giurgiu and Oltenita cities (Romania)

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Hydrological and morphological changes of the Danube River between Giurgiu and Oltenita cities. Climate changes and anthropogenic activities in the last centuries have modified the hydro-morphological characteristics of many rivers, including the Danube River. This study aims to analyze the hydrological regime of the Danube using data registered at the Giurgiu station and identify the spatio-temporal adjustments of the riverbed between Giurgiu and Olteniţa along a 151 years interval (1864-2015), as inferred from cartographic documents and satellite imagery. The results show major changes in the hydrological regime of the Danube, and also in the shape of the river channel. After the construction of the Iron Gates I and II upstream of the study area, the water level and sediment quantity have greatly dropped. Besides the changes in the hydrological regime, local anthropogenic interventions (dimming, draining, sand exploitation) have contributed to changing the watercourse. Through studying the Giurgiu-Olteniţa sector, we can add the Danube River among other European rivers displaying horizontal stability and a tendency of incising and narrowing of the riverbed.

Keywords: hydrological regime, morphological changes, Danube River, diachronic analysis

Schimbări hidrologice și morfologice ale Dunării între municipiile Giurgiu și Oltenița. Schimbările climatice și activitățile antropice din ultimele secole au modificat caracteristicile hidro-morfologice a multor râuri, printre care și al fluviului Dunărea. Prin acest studiu ne propunem să analizăm regimul hidrologic al Dunării utilizând date înregistrate la stația Giurgiu și să identificăm ajustările spațio-temporale ale albiei minore în sectorul Giurgiu-Oltenița (România), pe un interval de 151 de ani (1864-2015), având ca suport documente cartografice și imagini satelitare. Rezultatele arată schimbări majore atât în regimul hidrologic al Dunării, cât și în aspectul albiei minore. După construirea Porților de Fier I și II în amonte de sectorul studiat, nivelul mediu multianual al apei și cantitatea de sedimente au scăzut semnificativ. La schimbările survenite în regimul hidrologic se adaugă și intervențiile antropice locale (indigurări, desecări, exploatarea nisipului), toate aceastea contribuind la modificarea configurării cursului de apă. Interpretarea rezultatelor ne permite plasarea comportamentului Dunării, studiat pentru sectorul Giurgiu-Oltenița, în categoria altor râuri europene, caracterizate prin stabilitate în plan orizontal și tendință de incizare și îngustare a albiei.

Cuvinte cheie: regim hidrologic, schimbări morfologice, Dunăre, analiză diacronică
1. INTRODUCTION

The watercourse is able to form itself, as its shape is a result of erosion, transport and deposition of sediments. In time, the hydro-morphological characteristics may suffer changes as the watercourse will adjust depending on climate, various tectonic, geological or hydrological factors, and/or human intervention (Perşoiu, Rădoane, 2011). During the last centuries, in particular in the recent decades, many of the World's rivers have strongly been affected by human intervention through dams and reservoirs (Surian, 1999), levee which have disconnected rivers by floodplains, gravel or sand mining and pollution (Ricaurte et al., 2012). In this context, the river investigations have been a great challenge for the scientific community. For example, in Europe, the hydrological and planimetric changes of the rivers channels, especially to the anthropogenic influence, have been studied widely (Gurnell, 1997; Surian, 1999; Winterbottom, 2000; Liébault and Piégay, 2001; Pišút, 2002; Surian and Rinaldi, 2003; Kiss at al., 2009; Kiss and Andrási, 2011; Nagy and Kiss, 2016). The results of these studies highlight how the hydrotechnical works, sandy/gravel mining and land use change have offered to the many European river channel "a general tendency of incision followed by channel narrowing and lateral stability" (Perşoiu and Rădoane, 2011: 91).

One of the Europe's major rivers which have long been affected is Danube River. According to International Commision for the Protection of the Danube River (2015) the first human intervention was in the late Middle Ages and than the first dike system was build starting with 16th century. Later, the anthropogenic activities are representative by cut-offs of meanders in the 19th century and gravel mining from 1970 (Nagy and Kiss, 2016). All these interventions in the context of climate change (e.g. the period of the Little Ice Age and the warmer period after that) have accentuated the hydrological and the morphological channel changes (Perşoiu and Rădoane, 2011) for the Danube River. Over time there has been a scientific interest to follow the hydrological behaviour and morphological changes of the Danube River, both internationally (e.g. Pišút, 2001, Hohensinner et al., 2011; Ricaurte et al., 2012; Mladenovic et al., 2013; Nagy and Kiss, 2016) and also, nationally (e.g. Bondar and Buta, 1995; Bondar, 2000; Canciu, 2008; Vişinescu and Bularda, 2008; Gâştescu and Țuchiu, 2012; Posner, 2015).

This study aims to analyse the hydrological regime of the Danube using data registered at the Giurgiu gauge and identify the spatio-temporal adjustments of the riverbed between Giurgiu and Oltenița along a 151 years interval (1864-2015), as inferred from cartographic documents and satellite imagery. This analysis is part of a larger study, focused on the recent development of Danubian fluvial islets, and as such it should be noted that this article only follows the changes along the main watercourse.
2. STUDY AREA

The Danube, the second longest watercourse in Europe - 2,870 km (Giosan et al., 2005), originates in the Black Forest (Germany) and empties into the Black Sea through three branches: Chilia, Sulina și Sfântu Gheorghe, forming the Danube Delta (Buzea, 2010). Depending on the physical and geographical elements and the hydrological characteristics, there are three sectors: the Upper Danube (from its source to Bratislava), the Middle Danube (from Bratislava to Baziaș) and the Lower Danube (from Bazias to the Black Sea) (Tockner et al., 2008).

The Lower Danube overlaps the Romanian sector, representing the state border between Romania and Serbia, Bulgaria, Moldova and Ukraine (Buzea, 2010). In this sector, the river basin has an area of 237,068 km² – 29.4% of its total (Botzan et al., 1991), and a length of about 1,075 km (Gâștescu and Țuchiu, 2012).

In this paper, the focus is on the Danube riverbed in the Giurgiu-Oltenita sector (Figure 1). The length of the watercourse in this sector is of about 62 km, between milepost 493 (in Giurgiu) and milepost 420 (in Oltenita).

Figure 1. Danube River between Giurgiu and Oltenita cities: Location map
3. METHODS

In order to observe the changes in the hydrological regime of the Danube, at the Giurgiu station, a series of hydrological data have been analyzed. These include information regarding the maximum, minimum and annual means of the water level, as well as water and sediment discharges; part of this data has been extracted from the hydrological yearbooks, while others have been provided by the Giurgiu Lower Danube River Administration and S.G.A Giurgiu. Unfortunately, the dataset does not cover the entire intended interval, and as such, the hydrological data has been divided between multiple intervals: 1943-1968 and 2002-2015 (water level) and 1967-2015 (water and sediment discharges). It is important that the hydrological data are both from before and after the construction of the Iron Gates I and II dams and the beginning of structural work along the Danube; thus, the impact of human activities on the hydrological regime of the Danube may be observed.

The changes of the Danubian watercourse in the horizontal plane have been observed based on the cartographic documents and satellite imagery. From a large collection of cartographic documents that cover the Giurgiu-Oltenita sector, three sets of historical maps of similar scale have been selected; adding to these maps a satellite image in order to observe recent changes. The cartographic material and imagery cover the entire study area for an interval of 151 years (1864-2015). Reference data for this material are presented in the Table 1.

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Name (Source of download)</th>
<th>Year of reference</th>
<th>Scale/Spatial resolution</th>
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<tr>
<td></td>
<td>1:20,000 Romanian maps under Lambert-Cholesky projection system – called Planurile Directoare de Tragere (<a href="http://earth.unibuc.ro/download">http://earth.unibuc.ro/download</a>)</td>
<td>1920</td>
<td>1:20,000</td>
</tr>
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<td></td>
<td>Topographic Map of Romania (<a href="http://opengis.unibuc.ro/">http://opengis.unibuc.ro/</a>)</td>
<td>1980</td>
<td>1:25,000</td>
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The main watercourse and sandbars, as well as fluvial islets, have been obtained in polygonal format, through the process of digitization. Three maps have been obtained, showing the development in the horizontal plane of the Danube waterbed. It should be noted that as an inconvenience of using old cartographic documents and satellite imagery, the intervals between timepoints are not equals, and as such the data is not uniform. For this reason, the interpretation of the changes of the watercourse takes into
account the possibility of intermediate positionings, which have not been captured by 
existing cartographic documents. The interpretation and explanation of the extracted 
information have been based both on hydrological data, as well as bibliographical 
sources.

4. RESULTS AND DISCUSSIONS

Changes in the hydrological regime

Looking at the graphs in Figure 2 and Figure 3, the water level tends to decrease; 
the values between 2002-2015 are lower compared to the values registered between 
1943-1968. The mean water levels between 1943-1968 are, most years, over 350 cm; 
however, between 2002-2015, the values are lower than this value. The graph in Figure 
4 is very representative of the decreasing quantity of suspended sediment after the 
construction of the Iron Gates I and II, upstream of the study area.

Figure 2. Water level at Giurgiu gauge between 1943-1967

Figure 3. Water level at Giurgiu gauge between 2002-2015
Changes in the horizontal plane of the riverbed  
1864-1920 (56 years)  
There are two main processes that have defined the behavior of the riverbed between 1864-1920: i) sediment accumulation near the Smirda and Turtucaia islets, leading to their merging into the left bank of the Danube; ii) avulsions in the sector between mileposts 477 and 443 (Figure 5). The aggressiveness of the flood of 1895, but especially that of the flood of 1897, may be the cause of the avulsions that happened during this interval.

Figure 5. Changes in the horizontal plane of the riverbed between 1864-1920
Defining this time interval is the connection of the Danube riverbed with the floodplain, through numerous natural branches, who are designed to draw off some of the water during floods. At the same time, there are more fluvial islets, and the total area of the fluvial islets is increased. This can be explained by: i) maintaining a low water level, which favors the submersion of fluvial bars; ii) sediment discharge high iii) the accumulation in the riverbed of material resulting from banks erosion; iv) vegetation on the fluvial banks, transforming them into permanent geomorphological formations (fluvial islets).

1920-1980 (60 years)

During these 60 years, there have been two kinds of major events with important local effects on the morphology of the watercourse in the study area: I) hydrological events – between 1920-1980 there have been five floods with major impact: 1930, 1940, 1942, 1955 and 1970 (Pătruț, 2010) and ii) anthropogenic events – the construction of the Iron Gates dams upstream the study area and embankment works along the floodplain.

Overall, the riverbed has maintained horizontal stability (Figure 6). However, there is an obvious bending of the Danube bank close to Gostinu village, where the bank has become more and more convex, due to increased erosion (Nenciu, 2015).

Figure 6. Changes in the horizontal plane of the riverbed between 1920-1980
An explication for this behavior may be associated to structural works in the Giurgiu-
Oltenita sector, especially around Gostinu. These structural works consisted of damming
and drainage activities: the enclosure Malu Rosu-Gostinu was impounded between
1962-1963, the enclosure Gostinu-Prundu-Greaca was impounded between 1964-1966,
and the enclosure Chirnogi-Arges between 1948-1949 (Vișinescu, 2014). The main
effect of these works over the riverbed consist of the effect called “efectul de
încorsetare”, which may lead to significant increases of the water level and the
deepening of the floodplain through erosion (Vișinescu, 2014). Nenciu (2015) has
identified multiple causes: i) the wrong choice of the route of the first pier executed; ii)
during the elevation works of the 1963 dam, the convex and concave area of the
floodplain were not taken into account; iii) failing to take into account the distance that a
dam should be positioned from the river bank; iv) the forests and parks along the
watercourse were not by-passed, but instead cut down.

The number of river islets is still high. Furthermore, the total area increases by up
to 3,5 kmp in 1980. The first thought that comes to mind as an explanation is the high
amount of sediments, however, due the construction of the Iron Gates I and II (km 944,
respectively km 863), as well as the building of numerous dams along various important
tributaries, the yearly means of sediments have in fact decreased. Thus, the constantly
high amount of fluvial islets along this sector is explained by local control factors.

1980-2015 (35 years)

For this last interval in the analysis, the watercourse exhibits stability
horizontally, as there are only two area that have suffered major morphological changes
(Figure 7): i) near Giurgiu, the islets Cioroiu and Mocanasu have partially merged with
the left bank; ii) the temporary merging (only during dry months) of the Kalimok islet
with the right bank.

The number of fluvial islets is still high, however, there is a slight decrease of the
total area. This may be associated to the high incidence of major floods during this time
interval. Through these 36 years, there have four large floods along the Romanian sector
last hundred years was registered in 2006 (Teodor et al, 2010). These floods may be one
of the main causes of the disappearance of fluvial islets (especially smaller islets) and
the decrease of the area of these formations.
5. CONCLUSIONS

Historical hydrologic data and cartographic materials have the amazing potential to highlight the variability of the river channels. Using the diachronic analysis is significant for river investigations in understanding the channel dynamics and the behavior of the rivers in the context of the global climate changes and human pressure.

In the studied section of the Danube River, natural and anthropic factors influence the hydro-morphology of the river. The hydrological time series data have allowed to highlight that before the anthropogenic intervention, the variations in water level and discharge, and flooding have played an important role in the spatial changes of the riverbed. After the '40s-'50s, human activities along the riverbed have led to a completely different behavior compared to the one in its natural state. Thus, there is a high stability of the river between 1980-2015. A diachronic study of the cartographic documents and imagery reveals spatial mutations, occurring in time, of the Danube in the Giurgiu-Oltenița sector. In this regard, a series of maps have been made, highlighting the horizontal changes of the riverbed, for four reference years: 1864, 1920, 1980 and 2015. The hydro-morphological changes induced in time by a series of anthropogenic disturbances: the construction of the Iron Gates I and II upstream of the study area, the damming of the Danube floodplain, including of the entire Giurgiu-Oltenita sector, extracting sand from the riverbed, set the riverbed in the study area in a trend of other European rivers – imposing a pronounced horizontal stability with a tendency towards contraction (Winterbottom, 2000; Feier, 2015).
6. REFERENCES


INTERNATIONAL COMMISSION FOR THE PROTECTION OF THE DANUBE RIVER 2015. Historical patterns along the Danube’s course. Danube Watch. Available at:


