pp. 41-50 https://doi.org/10.7427/DDI.23.06

6. Evolution of danubian islets from Balta Ialomitei hydrographic system (Km 345-241) between 1908-2016

IORDACHE Gabriel*, Bondar Constantin, ANGHEL Sorin, MALAGEANU Marian

National Research and Development Institute for Marine Geology and Geoecology – GeoEcoMar, Bucharest
**Address of author responsible for correspondence: National Research and Development Institute for Marine Geology and Geoecology – GeoEcoMar, Bucharest, e-mail: gabriel.iordache@geoecomar.ro*

Abstract: The studied area is part of the Balta Ialomiţei hydrographical system and belongs to the lower sector of the Danube, being characterized by the many branches, secondary branches with islets between them, indicating a state of hydro morphological instability of the riverbed. The sector analysed in this paper is between the bifurcations with the Bala branch (Turcescu Islet) from km 345 and up to Vadu Oii, at the bifurcation with Borcea branch, at km 241.The hydrographic changes that occurred over time in the hydrographic nodes Danube-Bala and Danube-Borcea branch, have significantly affected the morph hydrography of the secondary branches. Thus, in the Bala-Danube bifurcation area, the consequences of riverbed changes were reverberated by increasing the takeover capacity of water by Bala branch to the detriment of Danube branch. This leads to a decrease in depths on the Danube branch at low waters, endangering the optimal depths for navigation, the occurrence of critical points for navigation downstream, changes of islets and the main elements of riverbed. Thus, along the analysed range, the number of islets present in the riverbed of the Danube decreased between 1908 and 1960, remaining constant and with minor changes until 1990, after which there was a consistent increase of the number of islets until the end of the study period in 2016.Also, it find an increase in the total length of the islets and also changes in their geometry and position, especially at the smallest of them.

Keywords: islet, Danube branch, critical points, hydrographic changes

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 (Perșoiu and 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).

Anthropogenic intervention along the Danube floodplain has occurred in various degrees since ancient times. Large-scale, intense changes occurred primarily during the communist period when most of the floodplain was used for agriculture. As a result of this phase, 3250 km of artificial levee were constructed on the main course of the Danube, of which more than 1100 km are located in Romania. In time, the narrowing of the streambed by anthropogenic levees led to an increase in current velocity and significant erosion of the riverbed (Constantinescu et al., 2015).

Also, the damming of Danube at the Iron Gates Gorge and of its major tributaries led to the creation of 340 artificial lakes along their courses and lowered drastically Danube's sediment discharge that feeds the current floodplain. Using a comparative cartography approach (maps and satellite imagery) we can observe the extensive human impacts after the large Iron Gates I and II dams were built. Islets along the Danube course have directly reflected all these hydrological changes over time (Constantinescu et al., 2015).

Fluvial islands are present in nearly all major rivers. They must therefore have some impact on the fluid mechanics of the system. A fluvial island is defined as a land mass within a river channel that is separated from the floodplain by water on all sides, exhibits some stability, and remains exposed during bank full flow (whereas a bar would be submerged) (Wyrick, 2005).
Another definition of fluvial islets says that are positive landforms, specific to the fluvial relief, which occur frequently by the deposition of alluvial deposits, where the river bed widens or decreases the slope, or the river receives a tributary with more or less rough alluviums than its own (Marin, 2017).
This paper analyse the hydrographic changes over time (between 1908-2016) in the hydrographic nodes of the Danube - Bala branch and the Danube - Borcea branch, which considerably affected the morph-hydrography of secondary branches. For analysis were selected five reference years: 1908 1960 1990, 2008 and 2016 to show the recent changes concerning the Danube islets from selected area.

The study presents analysis of the hydrological regime combined with old cartographic materials and analysis of recent satellite images, using GIS technology to illustrate the results.

Study area

The Danube River is the second longest river in Europe (2857 km), originating in the Black Forest of Germany at an elevation of 1078 m and discharging into the Black Sea via Danube Delta in Romania and Ukraine (McCarney-Castle et al., 2011).

The Danube River can be divided into three parts. The Upper Danube, from its source to its confluence with the Morava River at Bratislava (Slovakia), is characterized by a pluvio-nival flow regime with high flow velocities and low water temperatures. The Middle Danube, ranging from Bratislava to the Iron Gate dams (Romania/Serbia), has a low elevation gradient and flows through the lowlands of the Pannonian plain. The Lower Danube traverses the Romanian-Bulgarian lowlands until the Danube Delta at the Black Sea (Stagl and Hattermann, 2016).

Danube branch is part of the Lower Danube (Calarasi-Braila sub-sector), which is characterized by a floodplain of pond type, with the largest width, 15 to 25 km, with blow zing, the main levees are very wide, with heights of 3-10 m and secondary levees with lacustrine depressions (Posea, 2005).

Area of interest is included in the Balta Ialomita hydrographic system and is developed on terrigenous sediments. On this sedimentary lithology, the Danube River has created a numerous secondary branches, like Old Danube branch situated on the right side of the meadow, adjacent of Dobrogean Horst (Stănescu and Stănculescu, 1967).
The area studied in this paper is expanded between the fluvial landmark 345, located downstream of Bala branch (Turcescu islet) up to fluvial landmark 241 at Vadu Oii (Fig. 1), where the Old Danube and Borcea branch joins.

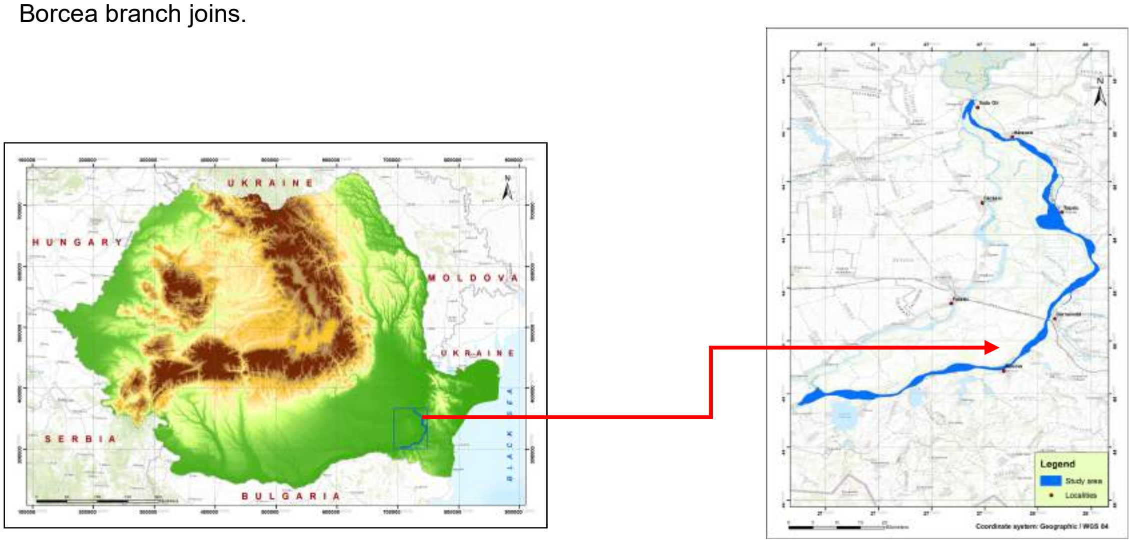

Figure 1 Study area localization on World Topographic Map

METHODOLOGY

Hydrographic changes produced over time in these two bifurcations have considerably affected the morpho-hydrography of secondary branches. To highlight these changes along the Old Danube branch between Bala bifurcation and the confluence with the Borcea branch, was made an inventory of the characteristics of the islets (name, position within the riverbed, width and length) for years 1908, 1960, 1990, 2008 and 2016. I chose these years for the analysis given that in year 1908, 1960 and 1990 were performed the hydrographic surveys by National Administration of Water Management in the proposed sector. Year 2008 was chosen as the intermediate year between the last hydrographic survey and 2016, but also because the available cartographic materials facilitated this option. Year 2016 was taken into account to highlight the latest situation of the state and evolution of morphological elements of the Danube branch riverbed.

In order to quantify the changes occurred on the Danube islets from the selected sector during 1908-2016, we analysed the hydrological regime of the Danube during 1921-2015. Available hydrological data are: the annual mean levels, water discharge and the annual mean suspended load discharge. Water levels were extracted from the publications of the Danube Commission from Budapest, Galati Lower Danube River Administration and from hydrological yearbooks.

Changes of the Danube riverbed in horizontal plane have been analysed and determined using cartographic materials and satellite imagery. Regarding the width of the Danube riverbed in the selected sector, we made measurements in 104 sections, whereby the riverbed widths were obtained at each fluvial milestone starting with km 345 (Turcescu Islet) and up to km 241, near Vadu Oii.

The cartographic materials used were historical maps such as: *The Danube Navigation Map of 1908, Austrian Topographic Maps - 1910, reprojected in Stereo 70, Danube Navigation Map between km 374 and km 234, scale 1: 25000, edition 1965 (elaborated after measurements from 1960)*, *Commission du Danube, PROFILE EN LONG DU DANUBE, de ULM (km 2586,3) a SULINA (km 0) - 1989*. Using the Navigation Maps of LDRA, 2003 edition, we made an important step in the study, namely the positioning of the fluvial milestone on the Old Danube branch. This operation was obtained by georeferencing all of the navigation map sheets from analysed sector using Global Mapper v. 16 software and creating a *SHP file* containing information about the coordinates (X, Y) and the name of milestone. Having this file with the above-mentioned positioning information, we began to measure the riverbed width. For year 2016, the measurements were based on satellite images provided by LANDSAT 8 OLI/TIRS, which were taken from the USGS (United States Geological Survey) site and NACLR orthophotoplans (*2008 edition*) for year 2008. Satellite imagery analysis was carried out using the specialized software ENVI version 5.1.

Both the islets and the Danube riverbed were obtained after georeferencing and digitizing maps as polygon format (Fig. 2). The parameters that define an islet were automatically calculated in the Global Mapper. The interpretation of the information obtained through the analysis of the cartographic materials was done both with hydrological data and with the reference sources.

Figure 2. Example of fluvial islet in polygon format and the main parameters of them

RESULTS

In the studied area there are two hydrographic nodes, namely the Danube-Bala branch node, located at km 345 and Danube-Borcea branch node at km 241. The analysis of the time variation of the two areas and of the riverbed between them was carried out.

Regarding the Danube-Bala hydrographic node at km 345, fig. 4, we found an increase in the width of the water access on the Bala branch from about 600 m in 1908 to about 750 m in 1960 and about 840 m in 1990. The increase in time of the riverbed width on the Bala branch led to an increase in the water take-up capacity from the Danube branch.

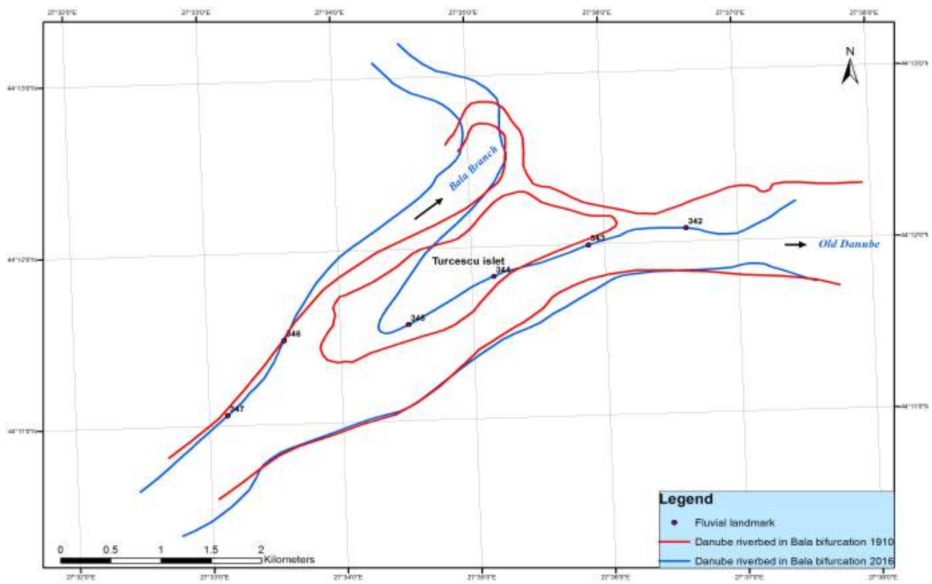

Figure 3. Bala branch – Danube bifurcation km 345 (1910 and 2016**)**

Subsequently, this situation has changed, namely the width of water access to the mouth of the Bala branch has declined reasonably due to the hydro-technical work done. Thus, at the level of 2008, the width of the mouth of the Bale was about 400 meters, so that in 2016 it would drop by half, having about 190 meters.

As mentioned above, the construction of the new jetty at the Bala branch mouth has drastically reduced riverbed width.
Also, considerable changes occurred in time in the area of the Danube - Borcea branch hydrographic node at km 241. As can be seen from fig. 3, in the confluence area of the Danube with the Borcea branch, there was in 1908 an islet named Gâsca that separate the Danube into two secondary branches, the Danube on the left and the Gâsca on the right side, and re-joined in unique Danube at km 240.8 (Bondar, 2004).

The confluence of the Borcea branch with the Danube took place at km 248.3. At the level of 1960, the Danube branch was atrophied between km 251 and km 248.3 (called the Saltava brook) with a tendency to close, the Borcea branch extending its riverbed downstream from km 248.3 up to km 241.
In the 1990s, the brook is totally clogged and the confluence of the Danube with the Borcea branch takes place at km 241 in the Vadu Oii-Giurgeni area (Bondar, 2004), a situation still encountered in 2016, as shown in fig.4.

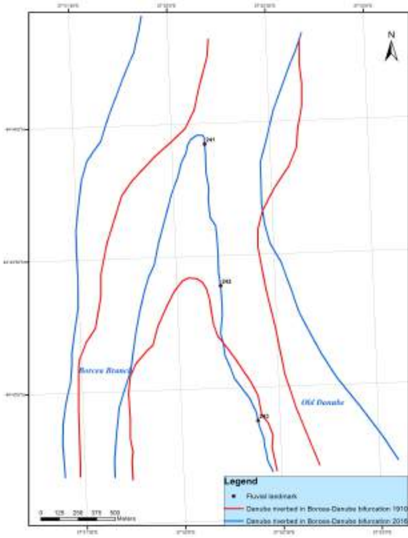

Figure 4. Borcea branch – Danube bifurcation km 241
(1910 and 2016)

One of the important factors influencing hydrological and hydrological changes is the anthropic factor. From the hydrological and hydrographic point of view, Balta Ialomiţei functioned naturally, until the embankment and drainage works started. Under natural conditions, this area had the role of attenuate the floods in the periods with high waters of the Danube. The situation was totally different after the finalization of the dams, so that at high waters, the surplus of existing water was not distributed in the area and it was totally directed downstream.

In the study of the islets evolution, the analysis of the hydrological regime changes must be carried out. We analysed the multiannual variation of the Danube levels at the Cernavodă and Hârşova gauge stations during the period 1921-2015 (Fig. 5).

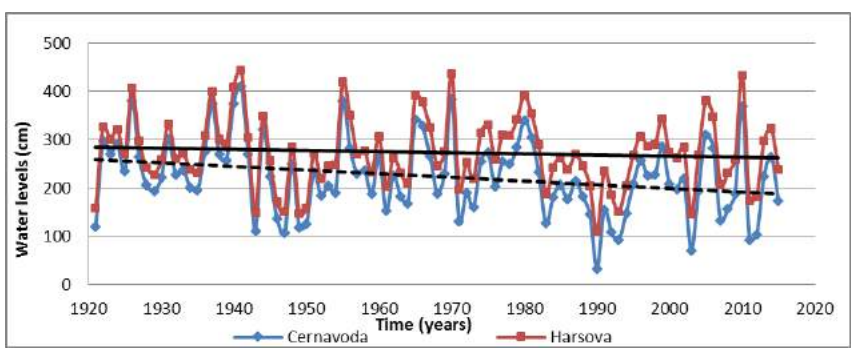

Figure 5 Multiannual variation of the average annual levels of the Danube at Cernavoda and Harsova between 1921-2015

Analysing the Figure 5, results the following:

- it is observed that the highest average annual rates of decrease in time of the Danube levels belongs to Cernavoda;
- the annual average Danube levels in the Balta Ialomita hydrographic system show a decreasing tendency over time;
- the highest annual average rates of decrease of Danube levels over time is recorded at the Cernavodă hydrometric station and has a value of -0.79 cm/year, and at Hârşova hydrometric station, the value is -0.26 cm/year;

As a conclusion of the previous figure, we can say that there is an appropriate synchronism of the time variation of the Danube annual average levels in the two locations studied.
In order to characterize the long-run water drainage regime on the Danube branch at Cernavoda and Hârşova, the average annual water flow rates for the period 1921-2015 were compiled. Figure 6 shows the variation of the average water flows at the two hydrometric stations, and there is a tendency to decrease at the Harsova station, but not as obvious as at the Cernavoda station.

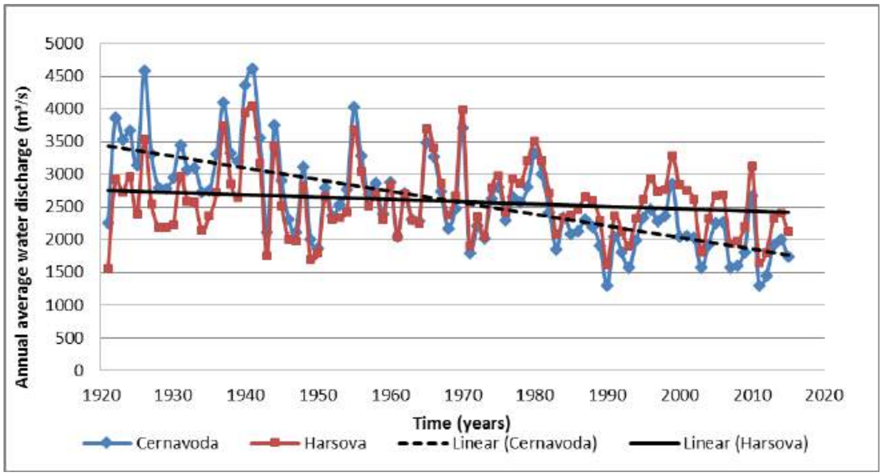

Figure 6. The variation of the average annual water discharge of the Danube at Cernavoda and Harsova during 1921-2015

Regarding the suspended sediment discharge, the graph of the variation of the average annual flows of suspensions on the Danube branch of the Cernavodă and Hârşova hydrometric sections for the years 1921-2015 (Fig. 7) was drawn up.

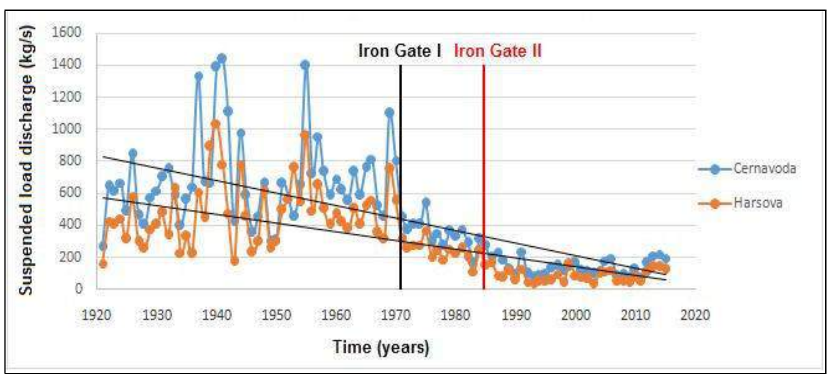

Figure 7. The variation of the average annual suspended sediment discharge of the Danube at Cernavoda and Harsova during 1921-2015

From the analysis of Fig. 7, it is noted the decreasing trend over time and the synchronism of variation of the average annual flows of suspended sediment in the two hydrometric sections. From the fig.7, result that there are two thresholds for decreasing the amount of suspended sediment, due to the construction of the Iron Gates I and II dams in 1970 respectively 1984.

The balance of the sediment discharge on the Danube branch between the Cernavodă and Hârşova hydrometric sections, allows the knowledge of the morphological processes in the riverbed that occur in the respective riverbed sector. From the analysis of the multi annual average discharge of the suspended sediment, results the mean values of suspended sediment are equal to 461 kg/s at Cernavoda and 316 kg/s in Harsova. The difference resulting from the input and output suspended sediment flows in the analysed riverbed sector, gives the value of the suspended sediment flow that participates in the morphological processes of the riverbed.

Between Cernavodă and Hârşova, the mean value of suspended sediment flow, for the period 1921-2015 is 145 kg/s with deposition effects on the entire route (between km 300 - km 253). A part from these sediments is cantoned in Danube riverbed and another part contributes to changes in dimensions and the formation of new islets.

After analysing the available materials, was obtained information about over time characteristics of the islets that are present in the Danube riverbed. Using GIS software, a few morphological parameters of the islets was calculated (position within the riverbed, average length and maximum width), which are mentioned in Figures (8, 9, 10, 11, 12).

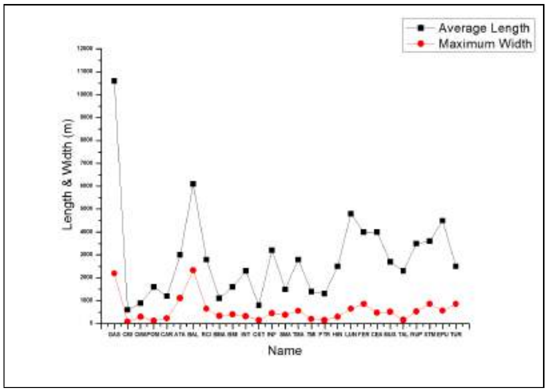

Figure 8. Situation of the islets in 1908

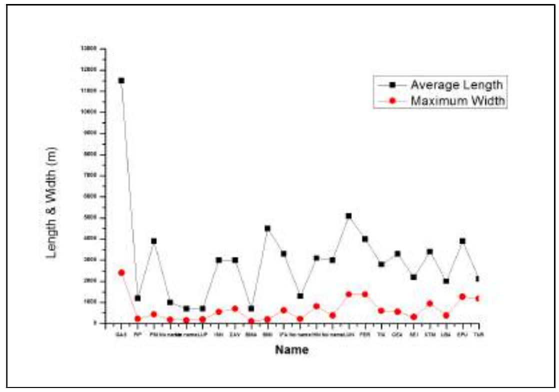

Figure 9. Situation of the islets in 1960

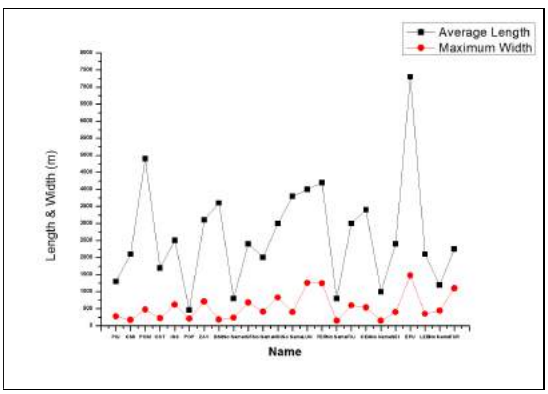

Figure 10. Situation of the islets in 1990

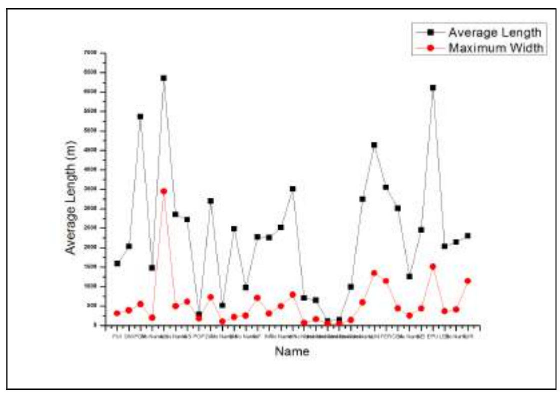

Figure 11. Situation of the islets in 2008

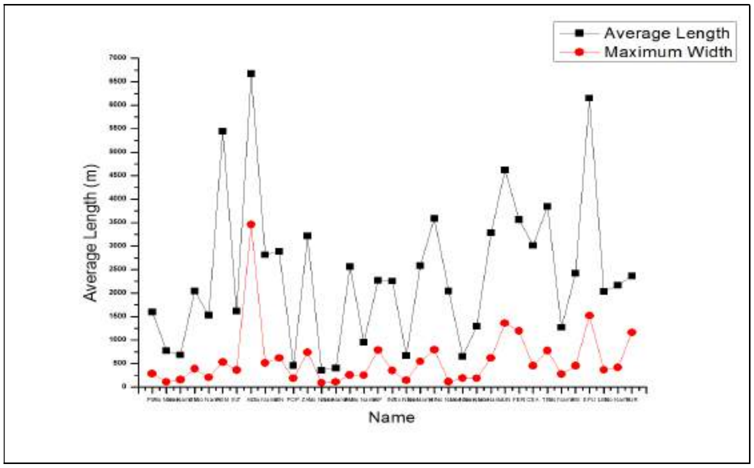

Figure 12. Situation of the islets in 2016

Analysing data presented in the figures above, were calculated the synthetic data of the morphometric characteristics of islets located along the Danube branch between KM 345 and 243 (Table 1).

Table 1. Morphometric characteristics of the islets

Morphometric characteristics of the islets	Years				
	1908	1960	1990	2008	2016
Total number of islets	27	23	24	31	35
Total length of islets (km)	77.4	76.3	62.9	73.8	84.2
Average length of islets (km)	2.86	3.32	2.73	2.38	2.40
Number of islets on the left side of the riverbed	7	12	9	9	13
Number of islets in the centre of the riverbed	4	0	1	3	3
Number of islets on the right side of the riverbed	16	11	13	19	19

The table above shows that the number of islets decreased since 1908 up to 1960, from 27 to 23, remaining almost constant until 1990, when recorded 24 islets (Bondar, 2004). After 1990, the number of islets increased to 31 in 2008 and 35 to 2016. This is due to the takeover of an increasingly more flow by the Bala branch to the detriment of the Danube. With regard to this issue, Bondar C., highlighted the following evolution of water discharge repartition on Bala branch and Danube downstream Turcescu islet. Thus, in 1921, the water discharge percentages on the Bala branch were 39% and on the right branch of Turcescu islet was about 56%. The natural phenomenon of increasing water discharge on the Bala branch continued, reaching the 56% in 2010, with a reduction of water flow downstream Turcescu islet with a percentage of about 32%. In the last 5 years, the annual decrease rate of water flow on Danube, downstream of Turcescu islet increase to 8 $m^3/s/year$ (Bondar, 2015).

In 2016, compared to 2008, 4 islets appeared, all on the left side of the riverbed. Most islets are located on the right side of the Danube riverbed. The average lengths of the islets range from 2.4 to 3.3 km, Turcescu being the most stable of the islets.

CONCLUSIONS

Hydrologic data and cartographic materials play an important role to highlight the variability of the riverbed. In the studied section of the Danube, natural and anthropogenic factors influence the hydro-morphology of the river. Substantial changes have been occurred both with regard to the hydrological regime of daily levels and water and sediment discharge.

Cartographic documents and satellite imagery reveals spatial changes of the Danube riverbed in the study area.

The analysis carried out in this study shows that considerable changes occurred in both hydrographic nodes (Bala-Danube and Borcea-Danube branches).

Over the years, the number of islets that are present in the Danube riverbed decrease during the period 1908-1960, remaining constant and with minor changes until 1990. After 1990 there is a consistent increase in the number of islets until nowadays. There is also an increase in the total length of islets and changes in the position of the smallest of them. Islets along the Danube course have directly reflected all these hydrological changes over time.

REFERENCES

Bondar C., 2004. Caracterizarea complexă a sectorului Dunării care prezintă interes pentru sistemul de funcţionare multiunitate de răcire cu apă CNE Cernavodă şi sistemul de primire a sarcinii termice pentru operarea ecologică de siguranţă, Arhiva GeoEcoMar, Bucureşti.

Bondar C., 2015. *Soluție hidraulică de redistribuire a debitelor de apă ale Dunării la ostrovul Turcescu*, Conferință Științifică Anuală a INHGA, Volum de rezumate, București 2015.

Constantinescu, Ș., Achim, D., Rus, I., Giosan, L., 2015. Embanking the Lower Danube: From natural to engineered floodplains and back, In: Hudson, P. and Middelkoop, H. (Eds.), Geomorphic Approaches to Integrated Floodplain Management of Lowland Fluvial Systems in North America and Europe, pp. 265-288, Springer.

Marin, A.F., 2017. Hydrological and morphological changes of the Danube River between Giurgiu and Oltenița cities (Romania). Cinq Continents (Revue Roumaine de Géographie), Volume 7/ Numéro 15, Bucharest, pp. 99-111.

McCarney-Castle K., Voulgaris G., Kettner A.J., Giosan L., 2011. Simulating fluvial fluxes in the Danube watershed: The 'Little Ice Age' versus modern day, *The Holocen*. 22 (I), pp. 91-105.

Perșoiu I., Rădoane M., 2011, Spatial and temporal controls on historical channel responses – study of an atypical case: Someșu Mic River, Romania. *Earth Surface Processes and Landforms,* 36, pp. 1279-1418.

Posea Gr., 2005. *Geomorfologia României: reliefuri, tipuri, geneză, evoluţie, regionare, Ediţia a II-a* - Editura Fundaţiei România de Mâine, Bucureşti, 328 p.

Stănescu V.Al., Stănculescu S., 1967. *Dunarea între Baziaș și Ceatal Izmail. Monografie hidrologică*. Editura Tehnică, București, 369 p.

Stagl J.C., Hattermann F.F., 2016. Impacts of Climate Change on Riverine Ecosystems: Alterations of Ecologically Relevant Flow Dynamics in the Danube River and Its Major Tributaries, *Water*, 8(12), 566.

Surian N., 1999. Channel changes due to river regulation: The case of the Piave River, Italy. *Earth Surface Processes and Landforms*, 24, pp. 1135-1151.

Wyrick J.R., 2005. *On the Formation of Fluvial Islands. PhD Thesis.* Oregon State University. USA, p. 284.

https://earthexplorer.usgs.gov/
http://www.geo-spatial.org/download/harile-austriece-1910-reproiectate-in-stereo70

Received 17 October 2017
Revised 13 March 2018