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A methodological framework for the morphometric analysis of the fluvial islets along the Danube River in the Giurgiu – Oltenita sector

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Abstract. This paper presents a methodology exclusively based on using the Open Source GIS Technology for the morphometric analysis of the fluvial islets along the Danube course. The study area corresponds to the Giurgiu-Oltenita sector, one of the sectors displaying a relative stability regarding the number and distribution of such geomorphological landforms. In order to identify and achieve a morphometric analysis of the Danubian fluvial islets, we suggest a set of eight parameters: the total number of fluvial islets, maximum length, maximum width, elongation ratio, area, perimeter, perimeter/area ratio and shape index. The necessary geospatial data used to compute the morphometric parameters have been obtained from cartographic documents and ortorectificated aerial imagery, while in order to obtain the final results, a graphical geoprocessing model has been created and run.

Keywords: *methodology, morphometric analysis, fluvial islets, Danube, graphical model, GIS*

1. INTRODUCTION

Geographical descriptions frequently refer to the shape of geographical elements. Until the 1960s, the shape of a region or geographical object has been mainly used as a descriptive device (Boyce, Clark, 1964). Subsequently, the need to quantify the shape of geographical elements has lead to the identification of a considerable number of mathematical parameters.

Currently, the evaluation of shape represents a challenge, as there is no unanimous agreement regarding a standard set of parameters needed to quantify shape. According to Sovik (2014), the parameters tend to fall into two categories: i) single parameters (for example, perimeter or area) and ii) multiple parameters – usually involving more complex mathematical functions.

Geographical information systems represent a modern technique of achieving an objective and complex analysis of the shape of a geographical element. Its popularity among the Earth Sciences has lead to numerous functionalities implemented in specialized computer software.

This article intends to illustrate a methodological framework for the morphometric analysis of fluvial islets, using open source software. The final results were obtained by running a conceptual model of the operations flow of such an analysis.

Fluvial islets are positive geomorphological landforms, specific to fluvial relief. Their occurrence, development and disappearance, are largely influenced by changes of the hydrological parameters and anthropic activities. Fluvial islets may have a biological, socioeconomic, and even geopolitical impact (Picco et al., 2014, Sadek, 2012).

In the literature, a number of significant studies have been conducted to investigate the morphology and morphometry of these landforms (Wyrich, 2005; Ricaurte et al., 2012; Kiss, Andrási, 2014; Raslan, Salama, 2015). Wyrich (2015) investigates the correlation between the shape of fluvial islets and the hydrogeomorphological processes occuring in the river bed. The author describes the morphology and morphometry of several fluvial islets along various north-American rivers, in regard to an elongation ratio. Kiss and Andrasi (2014) suggest a classification of fluvial islets based on this elongation ratio. The authors have identified four classes: I) an elongation ratio less than or equal to 2 shows a fluvial islet with a circular shape; ii) an elongation ratio greater than 2, but less than or equal to 4 shows a slightly circular shape; iii) an elongation ratio greater than 4, but less than or equal to 6 shows an elongated shape, while iv) an elongation ratio greater than 6 shows a strongly elongated shape.

Ricaurte et al. (2012) have analyzed the spatial distribution and geometrical characteristics of fluvial islets along European rivers affected by engineering works, thus distinguishing ten morphometric parameters (from the number of islets to density index). Equally ample descriptions of fluvial islets geometry, through morphometric parameters (length, width, elongation ration, perimeter, aria, density index) have been addressed by Raslan and Salama (2015). The authors have chosen as case study the alluvial islets along the Nile, in the sector between the Aswan and Esna dams.

2. STUDY AREA

We have chosen to apply the suggested methodology of computing the morphometric parameters based on GIS technology on the Danube sector situated between the Romanian localities Giurgiu and Oltenita (Figure 1). Specifically, the focus is on the fluvial islets along this sector.

The difference between a fluvial bar and a fluvial islet has been based on the absence or presence of vegetation (Figure 2).

We have chosen this sector because of the fact that, along the Lower Danube, this is the only sector with a relative stability regarding the number and distribution of fluvial islets. In the past three decades, a general downward trend has been noticed, regarding both the number, and the area of fluvial islets along the Danube (Constantinescu et al., 2015). This tendency may be explained through: I) the construction of the dams Iron Gates I and Iron Gates II, ii) the construction of dams along the Danube's main affluents, iii) lower sediment transport rates, iv) embanking works of the floodplain and v) frequent and aggressive floods.

Currently, between Giurgiu and Oltenita, there are a little over 20 fluvial islets, their number remaining relatively unchanging over the years.

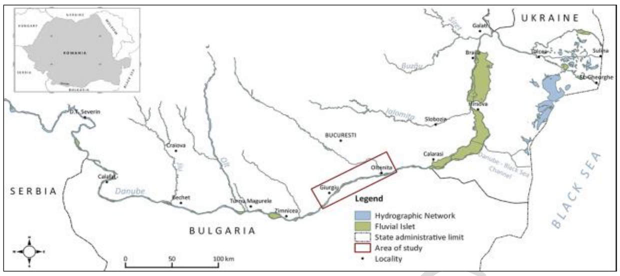

***Figure 1**. Localization of the study area*

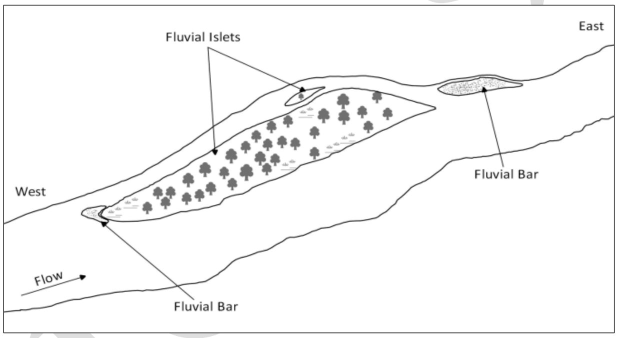

***Figure 2.** Identification and representation of fluvial islets and fluvial bars*

3. DATA PROCESSING

Using GIS technology to achieve a morphometric analysis requires a set of geospatial data in a format that is compatible with the software. Cartographic documents represent an important source to obtain historical data, allowing us to follow the evolution of geographical elements and phenomena.

We have selected four sets of historical maps and an ortophotoplan, spread over a total of 146 years (1864-2010). Five different years have been chosen as reference, corresponding to the following materials: *The Szathmary Map* (1864), *Islets Map* (1900), *Romanian maps under Lambert-Cholesky projection system* (1920), *Topographic Map of Romania 1:25k* (1980) și *Ortophoplan of Romania* (2010).

Out of the list of cartographic documents mentioned above, only *Islets Map* (1900) has been obtained non-georeferenced from Romanian Academy Library, The Maps Department. As such, the georeferencing process has been performed by us. As the map did not have a grid, we have opted for an image-to-image georeferencing, choosing as control points the geographical coordinates of milestones along the Danube. All cartographic materials were used in Romanian Stereo70 projection, Dealul Piscului Datum.

Subsequently, through digitization, positive geomorphological landforms, fluvial bars and fluvial islets have been extracted in polygonal format.

For each record, in the attribute table we have displayed both the attributes inferred by visual interpretation of the cartographic documents (for example, the type of landform, toponimy, the absence or presence of vegetation), as well as the morphometric attributes obtained by running specific algorithms implemented in Open Source GIS software.

4. AUTOMATION OF THE COMPUTATION OF MORPHOMETRIC PARAMETERS

To study the geometry of the fluvial islets, we have used a set of morphometric parameters, which have been computed for each of the five years used as reference (1864, 1900, 1920, 1980, 2010).

Morphometric parameter	Description
Total number of fluvial islets	The total number of fluvial islets along the study area
Maximum length	The maximum length of each islet, in meters
Maximum width	The maximum width of each islet, in meters
Elongation ratio	The ratio of the maximum length to the maximum width
Area	The area (m^2) of each islet, divided by 1000000 to convert to km^2
Perimeter	The perimeter (m^2) of each islet, divided by 1000 to convert to km
Perimeter/area ratio	The ratio of the perimeter to the area of each islet
Shape index	$100 * P/(2*\sqrt{(\pi*S)})$

***Table 1** Parametrii morfometrici calculați*

From a geometrical point of view, the fluvial islets along the Danube river have an irregular shape, and as such, computing mathematical parameters using computer software proves difficult. Computing the length and width of each graphical entity was performed through the Minimum Bounding Box (MBB) or Minimum Bounding Rectangle (MBR) method.

The method aims to find the rectangular box with the smallest area, within which the irregular polygon lies, rotated according to the orientation of the irregular polygon. Unfortunately, few Open Source GIS software have such a functionality. As such, it has been a challenge, both finding a way to automatically find the length and width of each fluvial islet, and finding the right software to do so. Eventually, we have opted for the WhiteBox GAT software (Figure 3).

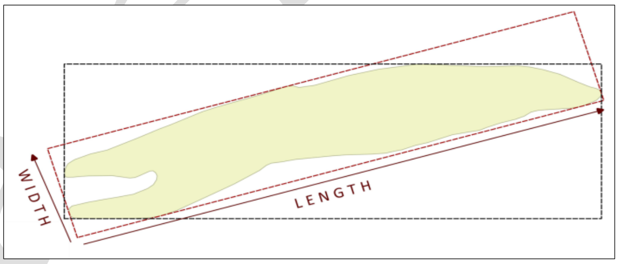

***Figure 3.** MBB/MBR in QGIS (dotted black line), and in WhiteBox GAT (dotted red line)*

To automate the work flow, the functions have been joined in a graphical model, using the Processing Modeler module from Open Source Quantum GIS. To compute the area, perimeter and elongation ratio, we have used the specific function from Quantum GIS, while to compute the perimeter/area ratio and shape index, we have used functions from a different Open Source GIS software: SAGA GIS (Figure 4).

The main components of any GIS model are: the input data, the function, and the output data. In this case, the input data is represented by the vectorial geospatial data (in *shp format), illustrating the geometry and attribute data of the fluvial islets. The functions are the tools implemented in the aforementioned software, and the output data is the numerical data in the attribute table of the input shapefiles.

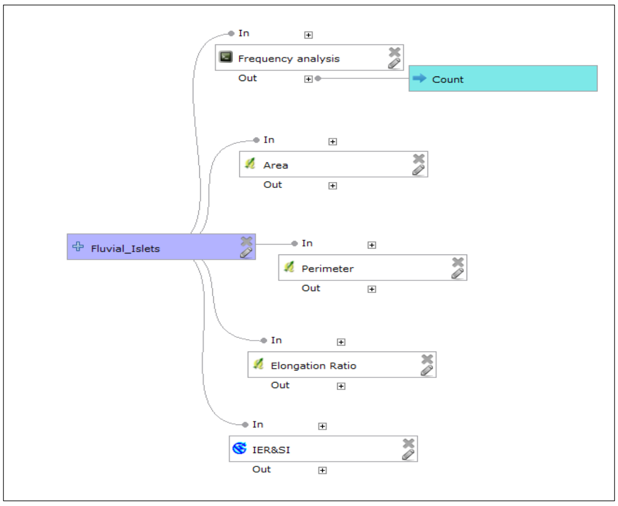

Figure 4. *Graphical Model*

4. RESULTS AND DISCUSSIONS

As a result of running the graphical model for each reference year, we have cataloged the fluvial islets (Figure 5) and computed the morphometric parameters mentioned in Table 1 (Figure 6).

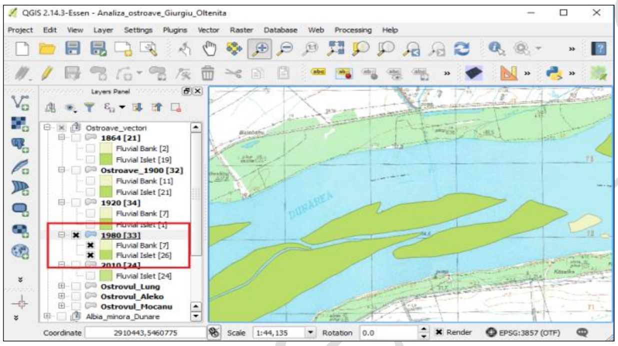

Figure 5*. The total number of fluvial islets and fluvial bars in the Giurgiu-Oltenita sector, shown in Quantum GIS (the red rectangle highlights an example for the reference year 1980)*

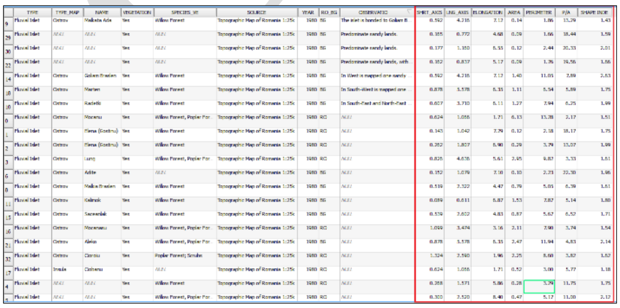

Figure 6*. The attribute table for the reference year 1980 (the red rectangle highlights the attributes added after running the graphical model)*

The output data may be visualized as a table, as seen in Figure 6, but also graphically (Figure 7), the latter proving more advantageous as a way to interpret the values of the morphometric parameters.

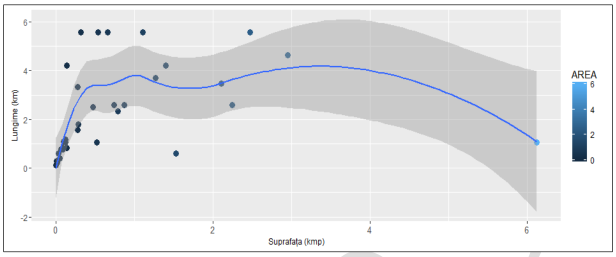

Figure 7*. An example of graphical representation of two morphometric parameters computed for the year 1980*

The results highlight a slight increase in the number of fluvial islets along the Giurgiu-Oltenita sector, with a total area ranging between 19.28 km² (1900) and 24.55 km² (1980). The elongation ratio values illustrate a tendency towards more elongated shapes, especially after 1980.

High values of the perimeter/area ratio (5-90) and shape index (1.2-3.0) showcase the irregular and complex shapes of the fluvial islets.

The irregular and elongated shape specific to the fluvial islets along the Danube may be associated to the erosion and accumulation process along the river bed, which in turn are influenced by a series of factors: water level, water discharges, sediment discharges, the frequency of floods and droughts, slope, currents, neotectonics movements, engineering works executed both upstream and in the study area.

5. CONCLUSION

This article presents a methodological framework based on using Open Source GIS Techniques, which allows the identification and morphometric analysis of the fluvial islets along the Danube course. As such, a set of eight parameters has been suggested: the number of fluvial islets, maximum length, maximum width, elongation ratio, area, perimeter, perimeter-area ratio, and shape index.

The automation of the computation of these morphometric parameters for the reference years has been performed by creating and running a geoprocessing model. Thus, a higher number of functions may be used, increasing efficiency. The graphical model may be used as an instrument through Quantum GIS software, aiming to perform the same kind of analysis for any other study area.

We believe that the suggested methodology offers a higher degree of objectivity in regard to the results, and is not as time-consuming compared to manually measuring and calculating the morphometric parameters.

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