ANALYSIS OF MORPHOMETRIC INDICATORS IN COASTAL HYDROGRAPHIC BASIN OF ROMANIA, USING GIS TECHNOLOGIES

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Abstract. *The goal of the paper is to conduct a comprehensive analysis of morphometric indicators within the Coastal Hydrographic Basin of Romania, utilizing Geographic Information System (GIS) technologies. In the current state of the field, morphometric analysis plays a crucial role in understanding hydrological systems and environmental management, particularly in regions with unique characteristics such as Romania's coastal area. The study uses a climatic dataset to gather essential climatic information. GIS tools are then employed to systematically evaluate morphometric parameters, including aridity index, watershed divide, basin area, shape, circularity and elongation ratio, and other relevant factors, providing a detailed and spatially explicit analysis of the basin's morphometric characteristics. The results of this analysis offer valuable insights into the hydrological and environmental conditions of the coastal area. However, it is important to acknowledge the limitations of the study, including potential constraints imposed by available datasets, which may limit the accuracy and depth of analysis. Nonetheless, the implications of the findings are significant for water resource management, environmental conservation, and sustainable development in Romania's coastal region. The study underscores the importance of integrating morphometric analysis into broader environmental management strategies and highlights the need for further research to enhance our understanding of coastal basin dynamics.*

Keywords*: morphometric indicators, hydrographic basin, coastal region, Geographic Information System (GIS).*

INTRODUCTION

Exploring hydrographic basins is crucial for effective resource stewardship and environmental preservation. In the context of climate change and anthropogenic activities, the Coastal Basin of Romania demands detailed analysis. Situated in proximity to the Black Sea, this basin showcases a variety of landscapes, from sandy beaches to wetlands and agricultural land, making it subject to diverse natural and anthropogenic pressures. Understanding these dynamics is imperative for informed decision-making and sustainable management practices.

Understanding the complexities of hydrographic basins such as the Coastal Basin of Romania requires a comprehensive approach that delves into their intricate dynamics. Morphometric analysis, a fundamental method in watershed assessment, provides valuable insights into the basin's characteristics, including its shape, size, and relief features.

Morphometric analysis stands out as a paramount method for comprehensively understanding the intricate relationships within watershed systems (STRAHLER, 1964). This analytical approach delves into various facets, encompassing linear, areal, and relief parameters, thereby providing invaluable insights into watershed characteristics (ABBOUD & NOFAL, 2017). Through detailed morphometric assessments, the influence of drainage morphometry on landforms and their attributes becomes discernible, contributing to a deeper understanding of basin dynamics (CHANDRASHEKAR ET AL., 2015).

Geomorphometry, characterized by the measurement and mathematical analysis of the Earth's surface and landform dimensions, provides a foundational framework for morphometric analyses (CLARKE, 1996). Employing GIS and remote sensing techniques has become commonplace in morphometric studies, owing to the reliability and accuracy of the results obtained (MAGESH ET AL., 2013).

Integration of these technologies enhances the precision and comprehensiveness of morphometric assessments, thereby contributing to informed decision-making in watershed management. Additionally, remote sensing techniques provide access to timely and high-resolution imagery, allowing for the monitoring of land surface changes over time.

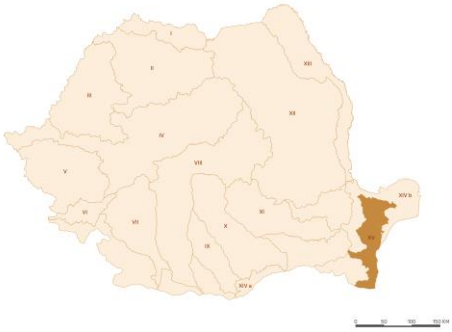


Figure 1. Map of the main hydrographic basins of Romania
Figure 2. Map depicting the Coastal Basin's alignment with the counties of Romania

Table 1

The names (Figure 1) and surfaces of the main hydrographic basins of Romania

Basin	**Name**	**Surface (km²)**	**Percentage (%)**
I	Tisa	4573.71	1.9
II	Someș	17885.65	7.5
III	Crișuri	14933.10	6.3
IV	Mureș	29513.21	12.4
V	Bega-Timiș-Caraș	13135.72	5.5
VI	Nera-Cerna	2769.78	1.2
VII	Jiu	10112.39	4.2
VIII	Olt	24052.01	10.1
IX	Vedea	5412.16	2.3
X	Argeș	12619.31	5.3
XI	Ialomița	10465.29	4.4
XII	Siret	42976.56	18.0
XIII	Prut	11105.95	4.7
XIV a	Dunăre (Danube)	23612.88	9.9
XIV b	Dunăre-Dobrogea	10122.93	4.2
XV	**Litoral (Coastal)**	**5432.01**	**2.3**

MATERIAL AND METHODS

The study focuses on a series of morphometric indicators that provide a detailed perspective on the physical and hydrological characteristics of the basin. The selected indicators, such as aridity index, watershed divide, basin area, its shape, and other parameters, are essential for the assessment and sustainable management of natural resources and the environment.

The paper aims to explore the morphometric characteristics of the Coastal Basin using Geographic Information System (GIS) technologies. In the context of the Romanian Coastal Basin, this approach is particularly relevant, considering the impact of human activities and the vulnerability of coastal areas to erosion processes. The use of GIS technologies allows for an integrated and spatial approach, fundamental for understanding phenomena at the basin level. Additionally, GIS analysis facilitates the visualization and interpretation of complex data, contributing to a better understanding and management of environmental risks.

The indicators developed in this study, derived from ZĂVOIANU, I., (2006): Hidrologie, 4th Edition, Bucharest, Editura Fundaţiei România de Mâine, constitute an essential part of our analysis, providing a solid foundation for evaluating and understanding hydrological processes within the specific context of our research.

RESULTS AND DISCUSSIONS

The analyses conducted in this study encompass a range of morphometric parameters, including the aridity index, watershed divide, average slope of the watershed divide, basin area, basin shape and form factor, circularity ratio, elongation ratio, shape ratio, average basin altitude, average basin slope, forest cover coefficient, and lake coefficient. These parameters provide valuable insights into the hydrological and topographical characteristics of the study area, shedding light on key factors influencing watershed dynamics and water resource management practices. Moreover, the utilization of quantitative analysis yields basin parameters in the form of ratios and dimensionless numbers, facilitating effective comparisons across different scales (KRISHNAMURTHY ET AL., 1996).

In the context of water resource management, especially in developing countries, numerous challenges arise due to factors such as unplanned development, limited economic resources, and inadequate adaptation measures (RAHAMAN ET AL., 2017). The pivotal role of water resource management in sustainable development initiatives was highlighted at the 1992 Rio World Summit on the United Nations Conference on Environment and Development (UNCED), emphasizing its significance in addressing global environmental concerns.

1. Aridity index (K)

The aridity index, defined as well as the climatic aridity, is an index that describes the dry and wet conditions of a site. Historically, the AI has been often used in long-term studies of geography and ecology. Recently, it has became one of the most frequently used climatic factors in studies of global change, especially in studies of climate change, ariditification and desertification (Meng & Zhang, 2004).

This index is calculated by considering two key variables: the amount of precipitation (P) and the air temperature (T), to assess the degree of dryness in a region.

The formula used is $K = P / (T + 10\ °C)$, where P represents the amount of precipitation (in mm), and T is the average temperature (in degrees Celsius). The calculation can be done monthly or annually, providing flexibility in analyzing climatic conditions over different periods.

For the studied hydrographic basin, the following dataset was used: Birsan, M-V.; Dumitrescu, A. (2014): ROCADA: Romanian daily gridded climatic dataset (1961-2013) V1.0. National Meteorological Administration, Bucharest, Romania, PANGAEA, https://doi.org/10.1594/PANGAEA.833627.

- The recorded temperatures are:

Maximum value = 11.417 °C

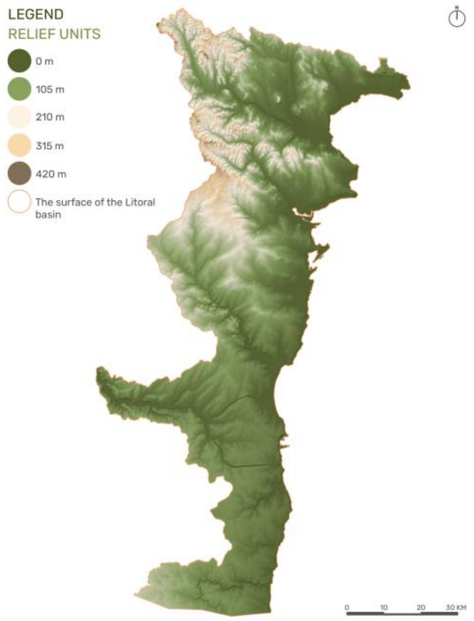
Minimum value = 8.837 °C

- The recorded precipitation is:

Maximum value = 469.367 mm
Minimum value = 376.62 mm
Average temperature: 10.61 °C
Average precipitation: 413.58 mm

➢ Aridity Index (K): 413.58 / (10.61 + 10 °C) = 20.06

The result indicates a relatively balanced level between precipitation and temperature, suggesting a climate that is not extremely arid but also not excessively humid.



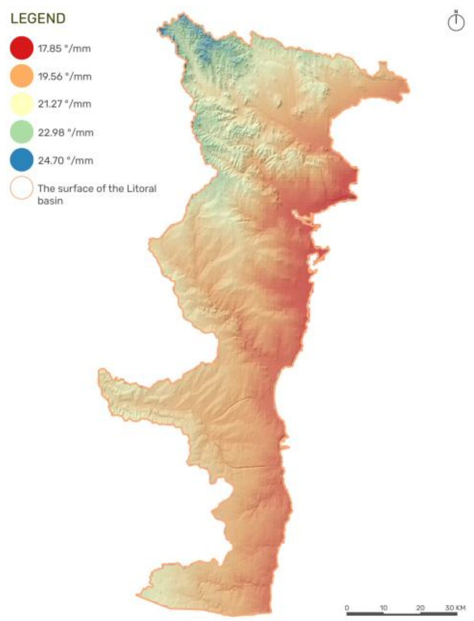


Figure 3. Hypsometric map (values ranging from 0 to 420 m)
Figure 4. Map of the aridity index (values recorded between 17.85 and 24.70 °/mm)

2. Watershed Divide (WD)

It is a geographical term referring to the line that delineates a hydrographic basin, separating the waters that flow in different directions. This analysis includes several important parameters: length, average elevation, and average slope.

- Length of WD

It represents the perimeter of the hydrographic basin, the total length of the line delineating the basin, expressed in meters or kilometers. This is a horizontal projection of the WD. For the Coastal Basin, P (length of WD) = 713,132.46 km

- Average Elevation of WD

It is calculated using a Digital Elevation Model (DEM), analyzed through geographic software such as Global Mapper.

For the Coastal Basin, the average elevation of WD = 103.45 m.

- Average Slope of WD

The average slope is calculated using the formula 2ΔH/P, where ΔH is the difference in altitude, and P is the length of the Watershed Divide.

Maximum altitude = 420 m

Minimum altitude = 0 m

P = 713,132.46

➢ Average slope = 2(420-0)/713132.46 = 2*420/713132.46 = 0.0000011779

0.00006749° (converted to degrees)

3. Basin Area

Representing the total land area drained by a system of water bodies such as rivers, lakes, and streams, and delimited by the watershed divide, the hydrographic basin is essentially the geographical space where all precipitation will flow and accumulate within that hydrographic system. For the Coastal Basin, the total area is 5432.01 km².

4. Basin Shape and Form Factor (Ff)

These are important parameters in the study of hydrology and geography as they influence how water collects and flows within a basin.

The Coastal Basin has an elongated shape in the NE-SW direction. This shape indicates that the length of the basin is greater compared to its width, which influences the speed of water flow and its distribution within the basin.

The calculation formula is $Ff = Sb/Lb^2$, where Sb is the basin area, and Lb is the length of the side of the square that has an equivalent area to the basin's maximum length.

The maximum length of the basin (L), measured between its extreme points equals 166.82 km / 166820 m.

Lb = 166820 m

Area of the square (with side Lb) = 166820 m x 166820 m => 27,830 km²

Sb = 5432.01 km²

Calculation of the Form Factor:

Ff = 5432.01 km²/27,830 km²

➢ Ff = 0.195

5. Circularity Ratio (Cr)

This is a useful parameter for understanding how a basin can collect and distribute its waters. It is calculated based on the formula Cr = Sb/Sc, where Sb represents the basin area, while Sc is the area of the circle that has the same perimeter (P) as the basin. The formula for Sc is $Sc = P^2/4\pi$.

As follows:

The perimeter length of the basin (P) = 713,132.46 km

The area of the circle (Sc) = $713{,}132.46^2/4\ \pi$ = 508,557,905,506/12.56 = 40,490,279,100.8

The basin area (Sb) = 5432.01 km² Rc = 5432.01 km²/40,490,279,100.8

➢Cr = 1.34

The result indicates a relatively high circularity ratio.

Although the Coastal Basin has a slightly elongated shape (according to the analysis of the form factor), it is not far from a circular shape.

The circularity ratio is used to estimate the efficiency with which precipitation is collected and drained within the basin. Basins with shapes closer to a circle tend to have shorter hydrological response times and a more uniform distribution of water compared to elongated basins. Generally, an Cr close to 1 indicates a more circular basin, while lower values indicate a more elongated basin.

6. Elongation Ratio (Er)

This is an index used to characterize the shape of a hydrographic basin. The calculation formula is Er = Db/Lb, where Db is the diameter of the circle with the same area as the basin, and Lb is the maximum length of the basin.

The formula for Db is $Db = 2\sqrt{Sb/\pi}$

Basin area (Sb) = 5432.01 km²

Calculating the radius (r) of the circle, we have $r = \sqrt{5432.01/3.1415\ (\pi)} = \sqrt{1729.11}$

$r = \sqrt{1729.11} = 41.58$ km

Thus, the diameter (Db = 2r) = 83.16 km

Maximum length of the basin (Lb) = 166.82 km

Er = 83.16/166.82

➢Er = 0.49

The closer Er is to 1, the closer the basin shape is to a circle, indicating a more compact basin. An Er below 1, as in this case, suggests that the basin is longer than it is wide, consistent with previous descriptions. The elongation ratio influences the speed and manner of water flow, as well as the hydrological response to precipitation events.

Elongated basins often have a longer concentration time, meaning that water requires more time to travel the entire length of the basin.

7. Shape Ratio (Sr)

It suggests the general shape of a hydrographic basin and it is calculated using the formula $Sr = Sb/(P/4)^2$, where Sb is the basin area and P is the basin perimeter.

Basin area (Sb) = 5432.01 km²

Basin perimeter (P) = 713,132.46 km

(P/4) represents the length of a square side with the same perimeter as the basin: P/4 = 713,132.46 km / 4 = 178,283.115 km

$Sr = 5432.01\ km^2/(178{,}283.115\ km)^2$

$Sr = 5432.01\ km^2/3178.48$

➢ Sr = 1.70

An Sr of 1.70 suggests that the basin has a fairly compact shape. The closer Sr is to 1, the closer the basin shape is to that of a circle, indicating a more compact and rounded basin. An Sr greater than 1, as in this case, suggests a shape somewhat more elongated than a circle, but still relatively compact.

The shape ratio is a valuable indicator for understanding the hydrological dynamics of a basin, influencing how the basin collects and responds to precipitation.

More compact basins tend to have a faster hydrological response time compared to more elongated ones.

8. Average Basin Altitude (Aba)

It is an important indicator for the physical and ecological characterization of the basin. For our studied basin, the recorded altitudes are:

Maximum altitude = 419.84 m

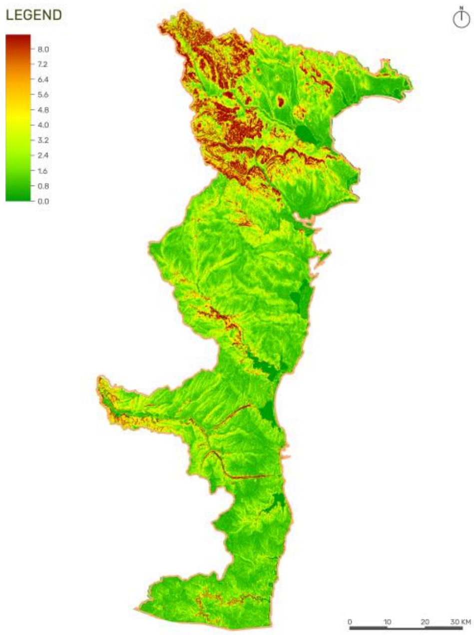
Minimum altitude = -3.74 m

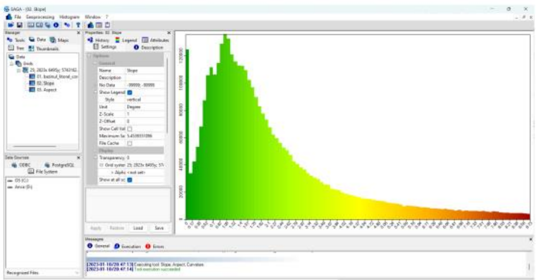
➢ Aba = 93.65 m

This value represents the average altitude of the entire surface of the Coastal Basin. The Coastal Basin, with an average altitude of under 200 m, falls into the category of lowland basins. Average altitude is a relevant factor for aspects such as climate, vegetation, soil types, and the hydrological regime of the basin.

Being a lowland basin, the Coastal Basin exhibits slower water drainage, higher flood risk under certain conditions, and an adapted biodiversity.

9. Average Basin Slope (Abs)





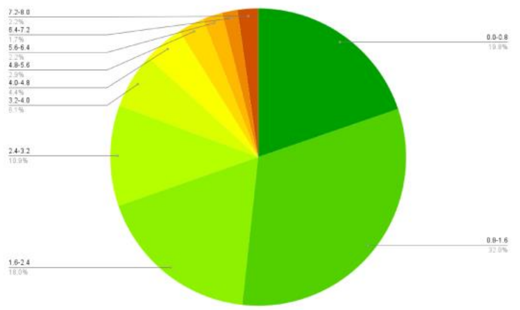


Figure 5. Average basin slope map

Figure 6. Histogram for the average basin slope. Figure 7. The graph of the average slope

The average slope represents a measure of the general incline of the terrain within the basin and is expressed in degrees.

For the Coastal Basin, it is considered:

➢ Abs = 1.6°

This result indicates a relatively moderate slope of the terrain.

Steeper slopes can lead to faster water runoff and more pronounced erosion, while gentler slopes, as is the case here, promote water retention and slower drainage. The Coastal Basin, with an average slope of 1.6°, is characterized by a low risk of rapid erosion, typical of lowland basins.

Understanding the slope of a hydrographic basin is vital for the design of hydraulic structures, for agriculture, and for soil conservation.

10. Forest Cover Coefficient (Fc) and the Lake Cover Coefficient (Lc)

The Forest Cover Coefficient (Fc) and the Lake Coefficient (Lc) are expressed as percentages and represent the proportion of the basin area occupied by forests and lakes. These can be visualized in the accompanying graphical representations (Figure 8 and Figure 9).

➢ Forest Cover Coefficient (Fc)

The calculation formula is Fc = (Sf/Sb)*100, where Sf represents the forested area of the basin, and Sb is the total area of the basin.

Fc = (1171.43 km²/5432.01 km²)*100

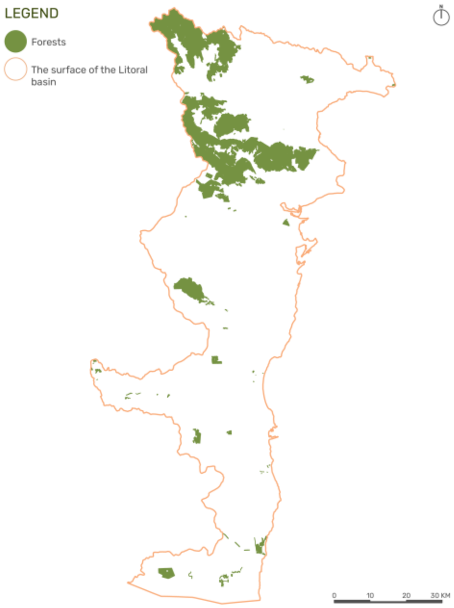
➢ Fc = 21.56%

➢ Lake Coefficient (Lc)

The calculation formula is Lc = (Sl/Sb)*100, where Sl is the area covered by lakes within the basin, and Sb represents the total area of the basin.

Lc = (798.07 km²/5432.01 km²)*100

➢ Lc = 14.69%



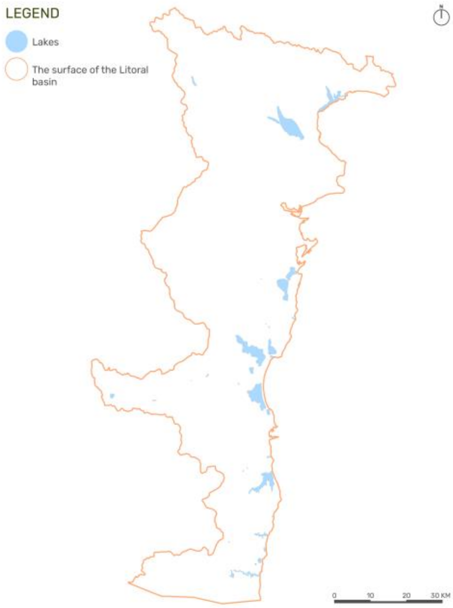


Figure 8. Forest cover area. Figure 9. Lake cover area

Forests significantly influence the water cycle within a basin, contributing to water retention and infiltration, reducing erosion, and influencing the local microclimate.

The presence of lakes within a hydrographic basin affects water retention, biodiversity, thermal regime, and water quality.

Table 2

Summary table

Nr. crt.	Indicator	Value
1	Aridity Index (K)	20.06
2	Watershed Divide Perimeter (P)	713,132.46
	Average Height of WD	103.45
	Average Slope of WD	0.00006749°
3	Basin Area	5432.01 km²
4	Shape Factor	0.195
5	Circularity Ratio (Rc)	1.34
6	Elongation Ratio (Ra)	0.49
7	Form Ratio (Rf)	1.70
8	Average Basin Altitude (Hmed)	93.65 m
9	Average Basin Slope (lb)	1.6°
10	Afforestation Coefficient	21.56%
	Lake Coefficient	14.69%

CONCLUSIONS

The GIS analysis revealed important characteristics of the Coastal Hydrographic Basin, such as variations in altitude, aridity index, and average terrain slope. The results of the analyzed parameters indicate a moderate climate, with a balance between precipitation and temperature, which is crucial for water resource management.

The moderate slopes suggest a low risk of erosion, favorable for agriculture and soil conservation. It is also emphasized the importance of conserving natural habitats and maintaining ecological balance.

The paper underscores the importance of an integrated approach in natural resource management, considering the impact of human activities on the hydrological and ecological balance of the basin. Additionally, multidisciplinary research in water resource management is recommended to understand the interactions between natural and human factors within hydrographic basins.

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