BULLETIN OF THE IRAQ NATURAL HISTORY MUSEUM
Iraq Natural History Research Center & Museum, University of Baghdad
https://jnhm.uobaghdad.edu.iq/index.php/BINHM/Home

Online ISSN: 2311-9799-Print ISSN: 1017-8678

Bull. Iraq nat. Hist. Mus.
(2024) 18 (2): 277- 295.
https://doi.org/10.26842/binhm.7.2024.18.2.0277

ORIGINAL ARTICLE

QUANTITATIVE ANALYSIS USING GEOSPATIAL MODELING OF AL-RAHIMAWI WATERSHED'S SHAPE PROPERTIES IN THE IRAQI SOUTHERN DESERT

Bashar F. Maaroof
Babylon Center for Civilization and Historical Studies, University of Babylon, Hillah, Babil 51001, Iraq.
E-mail: basharma@uobabylon.edu.iq

Recieved: 03 Feb. 2024, Revised:20 May 2024, Accepted: 29 May 2024, Published:20 December 2024

ABSTRACT

This paper included the study of Al-Rahimawi drainage basin, one of the watersheds in the Iraqi southern desert. It represents one of the hydro-geomorphological systems so-called Lower Valleys Region, according to the geomorphological division of Iraq. A set of geomorphometric parameters were used for the morphological characteristics of the Al-Rahimawi watershed, which gave precise consequences about this valley's geomorphological features and the erosive phase. The parameters used in this study are the circulatory ratio (R_C), form factor (F_f), elongation ratio (R_e), compactness factor (C_C), lemniscate ratio (k), and length/width ratio (R/W). In addition to using the digital elevation model (DEM) type SRTM and the satellite image of the American satellite Landsat ETM+8. The results indicated that the circulatory ratio was 0.154, suggesting that the watershed moved away from the circular shape. Also, the value of the form factor was low, reaching 0.098, which suggest that the watershed is close to the triangular shape. The results also demonstrated that the elongation ratio was low, reaching 0.353, indicating that the watershed is close to the rectangular shape. In addition, the value of the compactness factor was high, reaching 2.415. There is a rise in the lemniscate ratio, with a value of 2.551, indicating progress in the erosion cycle stages. The results suggested that the length-to-width ratio reached 5.054, which is a high percentage.

Keywords: Fluvial geomorphology, Geomorphometric analysis, Shape properties, Watershed modeling, Al-Rahimawi watershed.

INTRODUCTION

Geomorphometric studies of river drainage basins are one of the main and essential subjects in geomorphology of the recent trends in this major (Maaroof, 2022a). River drainage networks are the natural environment in which water moves in river basins and is affected by topographical characteristics (Das and Pardeshi, 2018). It is a natural reflection of it in the early stages of erosion but soon begins to form surface characteristics (MR *et al.*, 2019). The river's drainage networks reflect the geological, climatic, and vegetation situation (Maaroof and Kareem, 2022). A watershed is defined as any area of the earth's surface that is surrounded by a water dividing line and is covered by a wide network of Streams (Li *et al.*, 2018). Streams in the watershed vary in size and length, and according to the classification of Strehler (1957), the lowest order of streams begins at the water dividing line in higher elevations. The river orders gradually decrease until they reach the highest order, which represents the main river course that empties into either a sea, a lake, a marsh, or any other low-lying area (Höfle *et al.*, 2013).

Geomorphometry is the science of measuring the dimensions of the earth's surface (Prasannakumar *et al.*, 2011). This subject is concerned with measuring earth's surface features, according to the quantitative analysis principle, by applying mathematical equations and statistical methods to data derived from topographic maps, aerial photographs, satellite and radar images, and field measurements (Maxwell and Shobe, 2022). Geomorphometric results are used to classify the earth's surface and to identify the factors and processes responsible for its formation and evolution (Magesh *et al.*, 2012). The study of shape characteristics of river drainage basins depends on several geomorphometric parameters, most of which are based on the laws of Horton (1945), Strahler (1957), Schumm (1963), and other researchers.

The problem statement is represented in the spatial relationship between the geomorphological factors and processes on the one hand and the formation of the shape properties of the Al-Rahimawi drainage basin in the Iraqi southern desert on the other hand. The hypothesis indicated a significant spatial relationship between the physical factors (geological structure, surface, climate, and water resources) on the one hand and the formation of the shape properties of the drainage basin on the other hand.

There are several geomorphological studies relating to the geomorphometric analysis of shape properties. A multiscale river risk management method using detailed geomorphometric and hydro-geomorphological analysis of the main channel of the Carrión River Basin, Valencia, Spain, and it is proposed to classify riverine landscapes, taking into account anthropogenic variables (Lombana and Martínez-Graña, 2021). Also, a quantitative approach was implemented to study the basin of the Kermanasa River in the Ganga Plain (India) using geomorphometric parameters, where the drainage network was extracted from the SRTM data. This study helped in benefiting from water resources and expanding the sustainable development of the area surrounding the river basin (Prakash *et al.*, 2019). In addition, a geomorphometric analysis of the river drainage network of the Palar Basin, one of the major rivers in the south of peninsular India, was carried out to understand the drainage characteristics and drainage network geometry with reference tectonics. The geomorphometric analysis was performed using the "Azimuth and Drainage (BAD) Calculator" which is a new and straightforward methodology for extracting watershed parameters (MR *et al.*, 2019).

The aim of this study is to analyze the spatial relationships of the geomorphological factors and processes that led to the formation of the shape characteristics of the Al-Rahimawi watershed, and determined the nature of the geomorphometric variables that contributed to the development of the basin topographic system. The importance of this research comes from the fact that it sheds light on the most essential geomorphometric variables of the shape characteristics of the Al-Rahimawi drainage basin, one of the valleys of Al-Najaf plateau in the Iraqi southern desert. This is a promising area for investment due to its richness of natural resources. Awareness of the geomorphometric properties of the region contributes to the success of the region's investment planning in various fields (agriculture, industrial, residential, transport, etc.) In addition to the environmental importance of this watershed, it contributes to maintaining the sustainability of the ecosystem in the region (Al-Jiburi and Al-Basrawi, 2009; Jassim, 2009).

MATERIALS AND METHODS

Study Area : The Al-Rahimawi drainage basin is located in south-western parts of the Al-Najaf Desert in Iraq. It is bordered from the north, northwest, and west by the Al-Khuor watershed, which drains into the Al-Najaf Sea. To the east, it is the Abu-Khamsat Drainage Basin. To the south, it is bounded by the upper sources of the Hassab watershed (Ma'ala, 2009). Al – Rahimawi basin lies between latitude (43°16 53.5 E – 44°07 21.7 E) and longitude (31°23 56.3 N – 32°03 20.8 N) (Map 1). Its area is 1131.969 km^2 with a perimeter of 302.864 km, and the total length of the basin reached 107.474 km, starting from its upper sources near Al-Kharitin steppe and Shuaib Al-Saabiya that located west of Al-Kara area and ending with its mouth in the mainstream (upper order) of the Al-Khour drainage basin, which in turn, it flows into the Al-Najaf sea depression (Map 2). The mouth of the Al-Rahimawi drainage basin is 20 km away from the city of Al-Najaf, and the highest point in the basin was 320 m and the lowest height was 30 m above sea level (a.s.l) (Miletic, 1963; Al-Jiburi and Al-Basrawi, 2015). The watershed also stretches southwest to northeast (Map 3, Diag.1).

Al-Rahimawi watershed consists of four secondary basins (Map 4), which vary in their areal dimensions and can be described as follows:

1. Al-Rahimawi sub-watershed (1) (SW1): It is located in the northeastern part of the study area and has an area of 15 km^2, its perimeter is 26 km, and its length is 6.679 km (Tab. 1, Map 4).

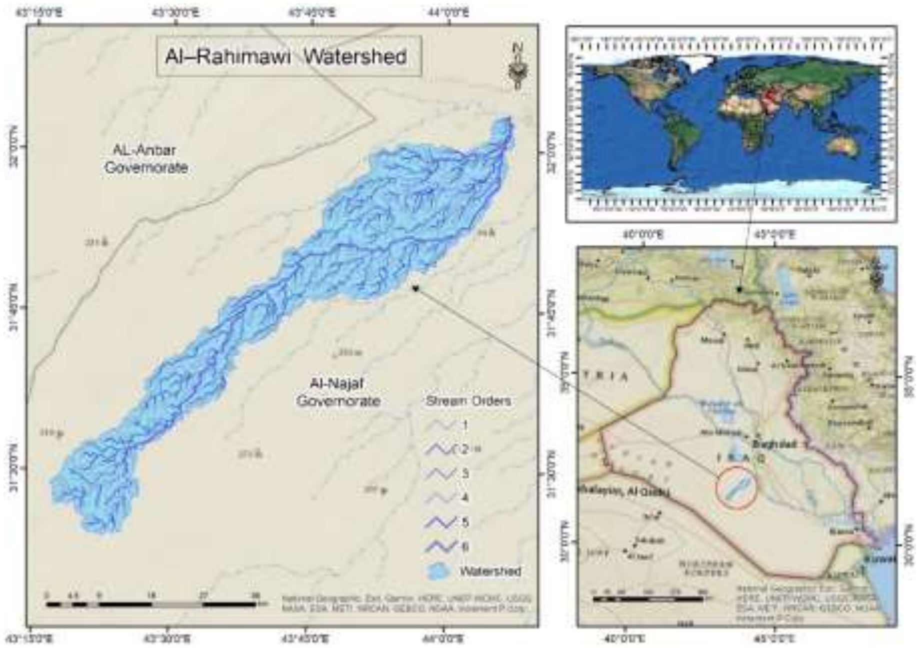
2. Al-Rahimawi sub-watershed (2) (SW2): It is located in the northwestern part of the study area and has an area of 240 km^2, its perimeter is 117 km, and its length is 41.577 km (Tab. 1, Map 4).

3. Al-Rahimawi sub-watershed (3) (SW3): It is located in the central parts of the study area and has an area of 136 km^2, its perimeter is 67 km, and its length is 24.327 km (Tab. 1, Map 4).

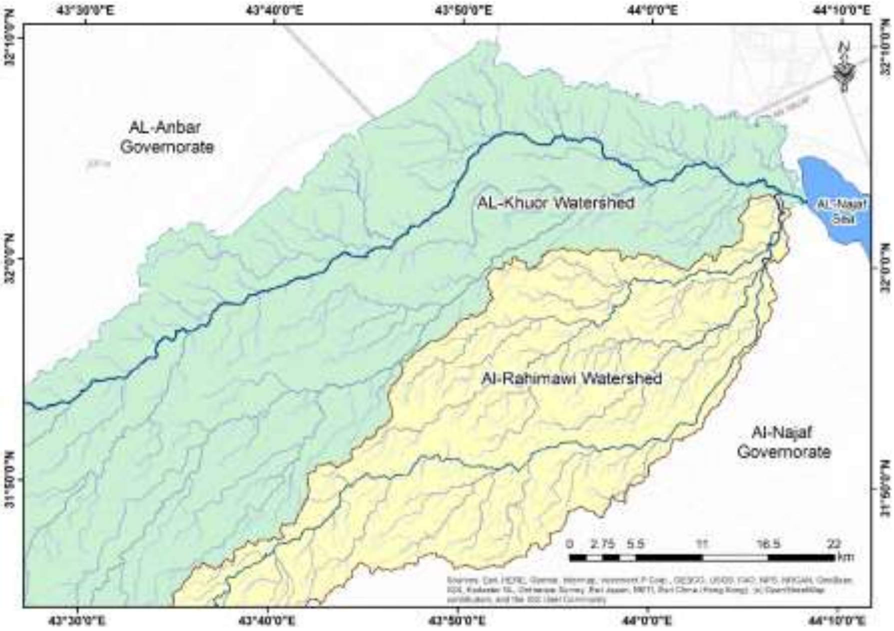
4. Al-Rahimawi sub-watershed (4) (SW4): It is located in the southern parts of the study area and its area is 741 km^2, its perimeter is 288 km, and its length is 101.831 km (Tab. 1, Map 4).

Table (1): Dimensions of Al-Rahimawi watershed and its sub-watersheds.

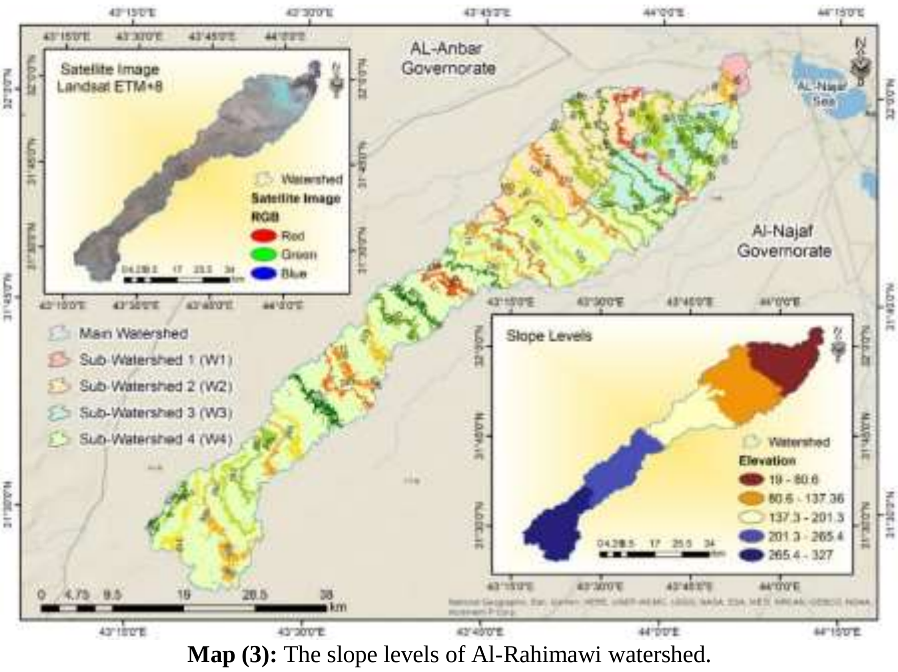
Watersheds	Area (km^2)	Perimeter (km)	Length (km)	Width (km)
Al-Rahimawi sub-watershed (1) (SW1)	15	26	6.679	4.416
Al-Rahimawi sub-watershed (2) (SW2)	240	117	41.577	10.315
Al-Rahimawi sub-watershed (3) (SW3)	136	67	24.327	10.518
Al-Rahimawi sub-watershed (4) (SW4)	741	288	101.831	12.106
Al-Rahimawi main watershed (RW)	1131.969	302.864	107.474	21.265



Map (1): Study area location from Iraq.



Map (2): The mouth of Al-Rahimawi watershed into Al-Khuor drainage basin.



Map (3): The slope levels of Al-Rahimawi watershed.

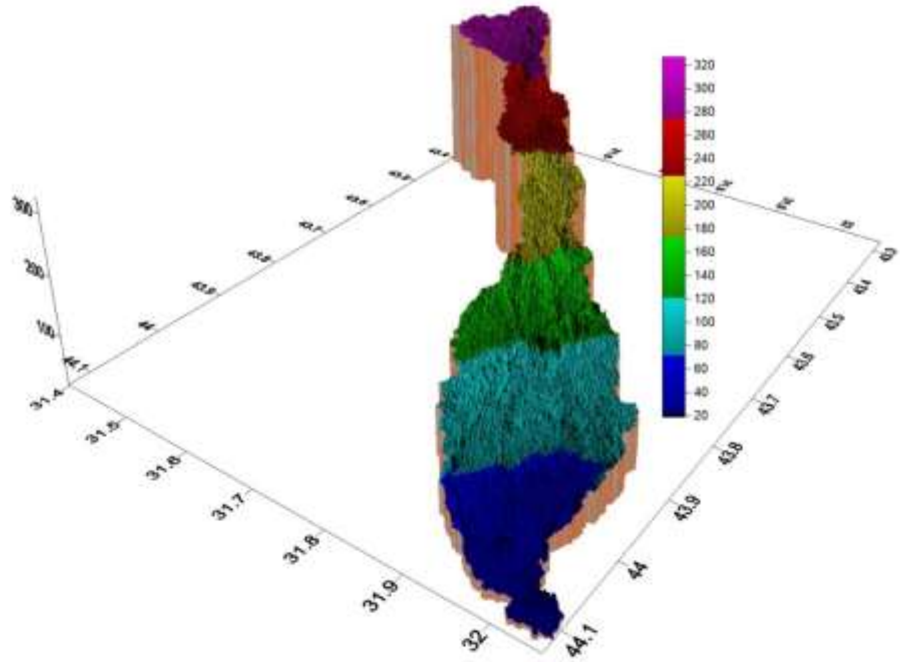
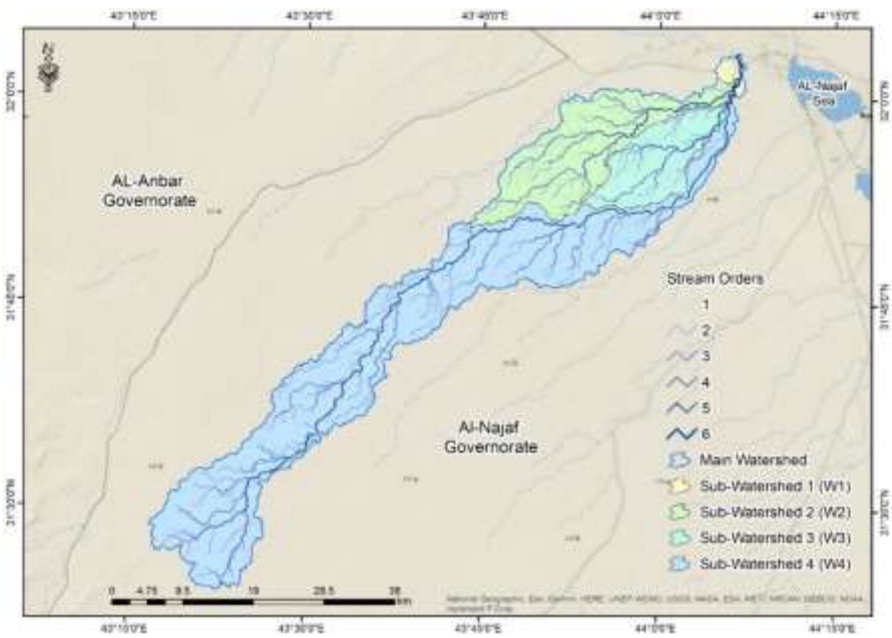


Diagram (1): The 3D model of Al-Rahimawi watershed.



Map (4): Al-Rahimawi Watershed and its sub-watersheds.

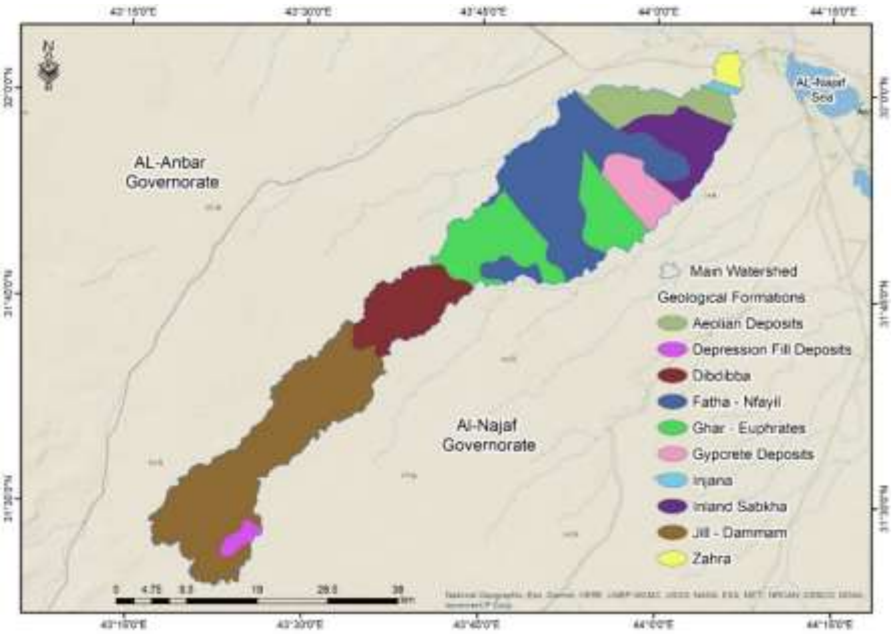
The climate setting in the study area does not differ much from what prevails in all regions of southern Iraq, which is characterized as a desert climate according to the Köppen classification (Maaroof, 2022b). According to the data from the Al-Najaf climatic station, it is clear that the study area is characterized by climatic extremes due to the irregularity of the climatic elements, particularly instead of especially temperature and rainfall. In addition it has a significant role in the geomorphological processes affecting the geomorphometric characteristics (Maaroof *et al.*, 2021). Climate data also indicate that the study area is characterized by two main seasons occurring during the year (Maaroof and Kareem, 2020). The warm season starts in early April to October, and the cold season runs from early November to the end of March (Agha and Șarlak, 2016).

The summer season is characterized by high temperatures and drought, particularly instead of especially in June, July, and August, as it reached 33.7°C, 36.6°C, and 36.2°C, respectively (Tab. 2). Meanwhile, the winter season is characterized by moderate temperatures with a downward trend. As average temperatures decline over the winter months of December, January, and February, when it reached 17.5°C, 16.7°C, and 14.5°C, respectively (Tab. 2). The high summer temperature and the decline in winter can be due to several reasons. The most important of which is that the astronomical location, which determines the variation in the intensity of the seasonal solar radiation and the length of the daily sunshine that is determined by the astronomical location and the invasion of the Siberian polar continental and tropical marine air masses in the cold season of the year, in addition, the invasion of the Siberian polar continental and tropical marine air masses in the year's cold season, apart from the depressions that lead to lower temperatures (Maaroof *et al.*, 2023). Meanwhile, the area is affected in summer by dry tropical continental air masses that raise the temperature (Salman *et al.*, 2017).

Table (2): The values of the climatic elements according to the data of the Al-Najaf climate station.

Months	Temperature (°C)	Rainfall (mm)
January	10.6	16.7
February	12.9	14.5
March	17.6	13.3
April	24.3	15.2
May	29.1	4.9
June	33.7	-
July	36.6	-
August	36.2	-
September	32.2	-
October	26.2	4.8
November	17.7	16.2
December	12.6	17.5
Average and Sum	24.1	103.1

According to the modern division of tectonic regions in Iraq, the study area is located within the Stable Shelf, between the Al-Salman, and Al-Dibaba ranges (Jassim and Goff, 2006; Al-Jiburi and Al-Basrawi, 2015). The region was exposed to several tectonic activities that began at the end of the Cretaceous period in vertical lifting movements accompanied by simple horizontal displacements in the bedrock (Ahmed *et al.*, 2022), where it resulted in ripples in the sedimentary cover, causing the emergence of forms of Horsts and Grabens. Besides the formation of numerous faults, which differ in their directorates-general according to the weaknesses in the rocks (Fouad, 2015). Many geological formations spread in the study area (Map 5), whose ages range from the upper Eocene era in the Tertiary to the Holocene era in the Quaternary time. These formations varied according to their sedimentation environment, as some were deposited under continental conditions resulting from the marine recession. In contrast, others were deposited under conditions resulting from marine advancement (Al-Jiburi and Al-Basrawi, 2009).



Map (5): Geological Formations of Al-Rahimawi watershed.

Data Collection: The geospatial characteristics of the Al-Rahimawi watershed have been analyzed and interpreted using the geomorphometric parameters listed in table 3. The geospatial data are from the Digital Elevation Model (DEM) type (SRTM) issued by the US Department of Defense. The satellite images of the Landsat ETM+8 bands of the US satellite for the year 2020 with a spatial resolution of 15 m were relied upon, in addition to using topographic maps on a scale of 1:100,000 issued by the General Authority for Iraqi Survey and geological and hydrological maps on a scale of 1:250,000 issued by the Iraqi Geological Survey. These data were incorporated into a topological model as raster layers after being entered into a GIS by Arc GIS V.10.8. The main watershed and sub-watershed were identified and derived in the form of vector layers, in addition to deriving the river drainage network at all its levels (Diag. 2). Other spatial analysis tools (software) have also been used, like Arc GIS Earth V.1.16, Surfer V.10, Global Mapper V.11, and Google Earth Pro V.7.1.

After the availability of an integrated geospatial database for the study area, it was moved to the stage of interpretation and geomorphometric analysis of the shape properties using a set of geomorphometric parameters. This was done within the framework of geomorphological analysis by linking and analyzing the factor, process, structure, and stage on the one hand and the formation of terrain features with geomorphometric dimensions on the other hand. Accurate and specific numerical indications were given to the dimensions of the topography in the basin, which were formed by geomorphological forces and processes, besides using the cartographic method to clarify the spatial dimensions of spatial features in the form of cartographic maps.

Table (3): Geomorphometric parameters of the shape properties used in this study.

Parameters	Formula	Description	Reference
Circulatory ratio (R_C)	$R_c= 4\pi A/P^2$	*A*: basin area (km^2); π= 3.14; *P*: perimeter (km)	(Strahler, 1957)
Form factor (F_f)	$F_f= A/(L_b)^2$	*A*: basin area (km^2); L_b: basin length (km)	(Horton, 1945)
Elongation ratio (R_e)	$R_e= 2\sqrt{(A/\pi)}/L_b$	*A*: basin area (km^2); π= 3.14; L_b: basin length (km)	(Schumm, 1963)
Compactness factor (C_C)	$C_c = P/2\sqrt{\pi A}$	P: perimeter (km); π: 3.14; *A*: basin area (km^2)	(Horton, 1945)
Lemniscate ratio (*k*)	$k= (L_b)^2/4A$	*Lb*: basin length; *A*: basin area (km^2)	(Chorley *et al.*, 1957)
Length-to-width ratio (*R/W*)	$R/W= L_b/W$	*Lb*: basin length; *W*: basin width (km)	(Miller, 1953)

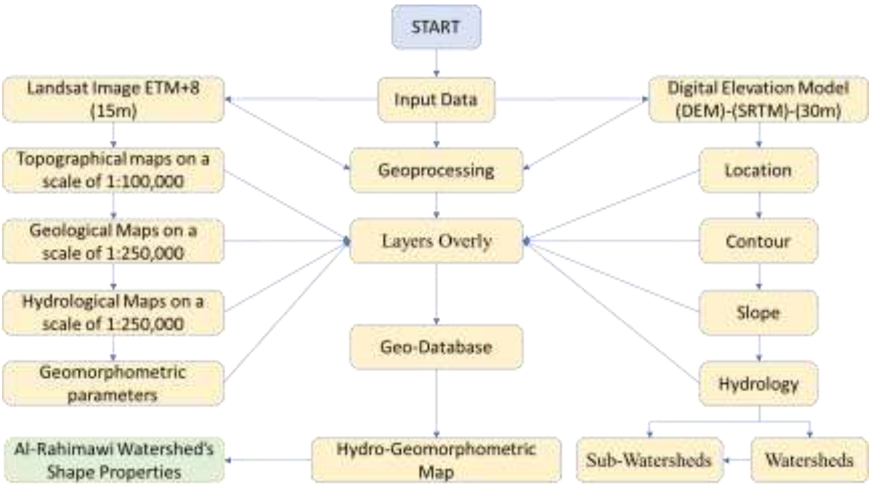


Diagram (2): Flow Chart of Methodology.

RESULTS AND DISCUSSION

Circulatory ratio (R_C): This parameter indicates the coupling of the river drainage basin with the circular shape. This law was developed by Strahler (1957) to describe how close the perimeter of the drainage basin is to a circular shape by comparing it to the perimeter of a circle with the same area as the basin, and this indicates that the result is close to No. 1. High values of this parameter indicate the presence of round-shaped drainage basins, while low values indicate meandering of the watershed lines of the river drainage basin. In many cases, the phenomenon of river capture has been observed in several river drainage basins due to the low values of the roundness coefficient (Strahler, 2010). The approach of the river drainage basin to the round shape indicates the progress of the geomorphological stage it is going through, as rivers usually dig and deepen their courses and then begin to expand them (Banerjee *et al.*, 2017).

The circulatory ratio of Al-Rahimawi main watershed (RW) was 0.154 (Tab. 4). This indicates that the basin is moving away from the round shape due to the tortuousness of the water dividing line and the variation in the lengths of the sub-watersheds. This led to an indentation of the basin boundaries in the areas occupied by the sub-watersheds such as Al-Rahimawi sub-watersheds 3 and 4. For Al-Rahimawi sub-watersheds, the ratios of circulation were variable. It was 0.278 and 0.380 for sub-watersheds 1 and 3, respectively, which are high percentages. For Al-Rahimawi sub-watershed 2, the circulatory ratio was 0.219, an average value. As for Al-Rahimawi sub-watershed 4, the ratio was 0.112, which is the lowest value recorded for this parameter at the level of all Al-Rahimawi sub-watersheds.

The low values of the circulatory ratio for sub-watersheds 2 and 4 indicate the tortuousness of the water division lines for each watershed and their irregularity. This affected the lengths of the lower-order water channels close to the headwaters, facilitating the river capture operations of the adjacent watersheds. As for the sub-watersheds 1 and 3, which recorded higher values for this parameter, this is due to the nature of the rock's low hardness, especially the dolomite rocks, which are subjected to continuous melting processes during the rainstorm. Also, the presence of several faults and linear structures and their intersection transversely with the extension of the watershed, in addition to the exposure of these watersheds to water erosion for long periods have contributed to the increase in the circulatory ratio. Hydrologically, round watersheds are characterized by an increase in the area of rain-fed areas and an increase in sedimentary yield. Also, the arrival of water to the main estuary quickly and the increase in the flood value with the increase in the discharge value.

Table (4): The shape properties of the Al-Rahimawi watershed (RW) and its sub-watersheds (SW).

Parameters	Watersheds				
	(SW1)	(SW2)	(SW3)	(SW4)	(RW)
Circulatory ratio (R_C)	0.278	0.219	0.380	0.112	0.154
Form factor (F_f)	0.336	0.138	0.230	0.071	0.098
Elongation ratio (R_e)	0.654	0.420	0.541	0.301	0.353
Compactness factor (C_C)	1.894	2.131	1.621	2.985	2.415
Lemniscate ratio (k)	0.743	1.800	1.087	3.474	2.551
Length/width ratio (R/W)	1.512	4.027	2.312	8.411	5.054

Form factor (F_f): By using this parameter, it is possible to identify the extent to which the shape of the drainage basin is close to or far from the triangular shape. Lower values of this parameter indicate that the basin is close to the triangular shape, and higher values mean that the basin is farther away from the triangular shape (Rai *et al.*, 2017). The value of the form factor of the Al-Rahimawi main drainage basin was 0.098, which is a low value, indicating that the shape of the basin is close to the triangular shape. This shows the similarity in the nature of the rocks' quality and the climate's nature. As for the difference in the values of this parameter for the sub-watersheds, it is primarily due to the local difference in the rocks and the dominance of the structural feature represented by faults and joints, which led to the elongation of some basins and their approach to the triangular shape. This is evident in Al-Rahimawi basins 1 and 3, where the values were 0.336 and 0.230 for each, respectively.

Form factor characteristics influence the hydrological regime of a river drainage basin. Rectangular basins are characterized by regular water discharge over time and relatively slow discharges compared to circular basins (Rai *et al.*, 2018). This is due to the exposure of the discharge quantities in the first case to the factors of leakage and evaporation during the run-off process from the source to the downstream. On the other hand, the circular basins are characterized by water flow that is irregular in time and with relatively high drainage during the periods of winter and spring floods. This is due to the high waves reaching the estuary from the water-feeding areas (Rai *et al.*, 2017).

The value of the form factor parameter affects the speed of high-water waves reaching the mainstream and its annual flow regime. This matter affects by any means the river's geomorphological processes, represented by erosion, weathering, transport, and sedimentation. In the case of a decrease in the value of the form factor, it is close to the triangular shape, as the source forms the head of the triangle, while the downstream region forms the base of the triangle. This can be seen clearly in Basins 2 and 4, where the river discharge peaks in a very short period after the rains fall, and the time required for the arrival of the flood wave from the source to the estuary decreases, and this has implications for the speed of performance of geomorphological processes. The opposite occurs in the case of the upstream area, which is the base of the triangle, where it is noticed that the water arrives sequentially and not quickly, due to the distance of the streams and spillways from the downstream area and the lack of risk of flooding with the widening of the area of the basins at the source and their narrowness at the downstream.

Elongation ratio (R_e): This parameter is considered one of the most accurate morphometric parameters for measuring the shapes of river drainage basins. Proposed initially by Schumm (1963), this parameter compares the shape of a river drainage basin to that of a rectangle. The values of this parameter are higher in extended drainage basins. At the same time, they are lower in basins whose shape is far from rectangular and where their width differs from their longitudinal extension (Soni, 2017). The values of this parameter range between 0 and 1, and whenever the values are close to zero; this indicates that the basin is close to a rectangular shape. If the values are higher than one, this suggests that the basin is close to a circular shape (Pandi *et al.*, 2017).

The data presented in Table 3 indicate that the elongation ratio of the Al-Rahimawi main watershed was 0.353, which is a relatively low value, suggesting that the basin is close to its rectangular shape. As for the Al-Rahimawi sub-watersheds, their values varied in the ratio of this parameter, as they reached 0.654 and 0.541 for the sub-watersheds 1 and 3, respectively, which are high values indicating that these two sub-watersheds are far from the rectangular shape and close to the circular shape. The values were 0.420 and 0.301 for sub-watersheds 2 and 4 each, respectively, which are low values indicating that these two sub-watersheds are close to the rectangular shape.

Basins that include diverse and heterogeneous geological formations and have been affected by faulting and folding processes tend to be more rectangular (Fenta *et al.*, 2017), and this applies exactly to sub-watersheds 2 and 4. The low elongation ratio in sub-watersheds 2 and 4 gave a clear geomorphological indication of the tendency of lower-order streams to increase their length and decrease their number. As for the increase in the elongation ratio in sub-watersheds 1 and 3, it indicated an increase in the number of lower-order streams and a decrease in their lengths. The low elongation rate in some sub-watersheds suggests that they are at the beginning of the youth phase of the erosion cycle, where the basin digs its channels and increases their lengths through retrograde erosion and does not practice lateral erosion that ends with an increase in the width of the basin. Also, the low ratios of this parameter indicate the hardness of the watershed rocks and their strong resistance to erosion processes. This led to the delay in the transition from the backward vertical erosion stage to the lateral erosion, the lack of water discharge due to evaporation and percolation that leads to sedimentary yield, and the delay in the arrival of the flood due to the long distance.

Compactness factor (C_C): This coefficient shows the homogeneity and consistency of the shape of the perimeter of the drainage basin and its catchment area (Yadav *et al.*, 2014). In addition to knowing the proximity or distance of the perimeter of the drainage basin from its center and the regularity of the water dividing line (Gajbhiye *et al.*, 2014). The results of applying this parameter indicate the geomorphological stage that indicates the geomorphological stage the drainage basin passes through. High values of this parameter indicate that the drainage basin is characterized by a large perimeter at the expense of its total area. Then, low values of this coefficient indicate the progression of the basin in the river erosion cycle (Sreedevi *et al.*, 2013).

The compactness factor of Al-Rahimawi's main watershed was 2.415, and the values of the sub-watersheds varied considerably, reaching 2.131 and 2.985 for sub-watersheds 2 and 4, respectively, which are the highest values. At the same time, the values were 1.894 and 1.621 for sub-watersheds 1 and 3, respectively. The relatively high value of the compactness factor of the Al-Rahimawi main watershed indicates the asymmetry of the shape, an increase in the tortuousness of the perimeter, and the recent erosion cycle that it passes through. This analysis is fully applicable to sub-watersheds with relatively high values. Still, the matter is different for sub-watersheds with low values of this coefficient, such as basins 1 and 3, which were characterized by an increase in their areas at the expense of the length of the perimeter, and this is a clear indication that these watersheds are going through advanced stages of the erosion cycle.

Lemniscate ratio (k): This modulus, proposed by Chorley (1957), compares the shapes of a drainage basin and a pear. The discovery of this equation was supported by the observation that most of these symmetrical river drainage basins have a pear-like shape rather than the more typical circular shape (Chorley *et al.*, 1957). Low values of this parameter show an increase in the drainage basin's lemniscate, indicating an increase in the lengths of the water channels and their numbers in the lower orders along the water division lines (Rai *et al.*, 2018). Additionally, low values of this coefficient show long-term dominance of vertical and lateral erosion processes, indicating the drainage basin's advancement in the erosion cycle, and high values of this coefficient show the opposite (Rai *et al.*, 2017).

Al-Rahimawi watershed's lemniscate ratio was 2.551, a relatively high figure that shows the river erosion in the basin is still in its early phases. It is apparent that the basin's inability to advance in the erosion cycle, which has affected the increase in the lemniscate ratio, was caused by the quality of the rocks, the region's structural condition, and the impacts of the climate. As for sub-watersheds, their values for this coefficient varied, reaching 0.743 for sub-watershed (1), the lowest value recorded at the level of sub-watersheds. This indicates that this sub-watershed has achieved remarkable progress in the erosion cycle within the main basin. The sub-watershed 4 has the highest recorded value, reaching 3.474, and this indicates that it is the least lemniscate of the watershed and naturally tends to elongate. The high value of sub-watershed 4 suggests that it is the least developed sub-watershed, and it still has a long period before it achieves significant progress in the river erosion cycle. The delay of sub-watershed 4 in the erosion cycle is the influence of geomorphological controls that delayed its development, and the type of rock and geological structure may be among the most important. Average values of 1,800 and 1,087 were noted for sub-watersheds 2 and 3, respectively. This indicates a low lemniscate ratio and their semi-square shape, possibly due to the region's tectonic activation.

Length/width ratio (R/W): To some extent, this parameter is similar to the elongation ratio parameter, with the difference that higher values indicate that the watershed is close to a rectangular shape (Rai *et al.*, 2018). Low values of this parameter approaching zero indicate an increase in the width of the basin concerning its length, which is the opposite of the elongation ratio parameter (Banerjee *et al.*, 2017). The length/width ratio of the Al-Rahimawi watershed was 5.054, which is a high ratio, indicating its closeness to the rectangular shape. The high value of this parameter indicates that the Al-Rahimawi watershed is still in the middle phase of the river erosion cycle and that the current drought conditions may continue this phase for a long time.

The sub-watersheds varied in their values, reaching 8.411 for the secondary watershed 4, which is a high value reflecting the geomorphological and geological conditions that this watershed goes through, especially the influence of the tectonic condition. The tectonic activation of the region contributed significantly to reducing the number of water channels, which led to a lack of erosion processes and an increase in the basin's length relative to its width. The value of this parameter was 1.512 for sub-watershed 1, which is the lowest recorded value. This decrease in value indicates that sub-watershed 1 is close to a circular shape due to the geomorphological conditions that control it, which led to an increase in the number of water channels that increased the width of this sub-watershed relative to its length. As for the rest of the sub-watersheds, their values were 4.027 for sub-watershed 2 and 2.312 for sub-watershed 3, which are average values that reflect their geomorphological conditions that worked to shape their characteristics.

CONCLUSIONS

The low circulatory ratio of the Al-Rahimawi watershed indicates that the water division line is irregular and diverges far from the circular shape, due to changes in the lengths of the sub-watersheds. The low circulatory ratio of the sub-watersheds also affected the lengths of the river channels of the lower orders near the headwaters. The decrease in the value of the shape factor of the Al-Rahimawi watershed indicates that it is close to the triangular shape, and this naturally results from the similarity in the quality of the rocks and the nature of the climate. The sub-watersheds varied in the form factor values between high and low, and some of them recorded high values as in the sub-watersheds 1 and 3. The high value of the shape factor indicates that the watershed is close to the rectangular shape, which affects the hydrological system, where the water discharge is relatively slow and regular.

The low value of the elongation ratio of the Al-Rahimawi watershed indicates that it is close to the rectangle shape. This decrease in the value of the elongation ratio naturally results from the diversity and heterogeneity of geological formations, which is a clear geomorphological indicator of the tendency of lower-order water channels to increase their lengths and decrease their number. The high value of the compactness factor of the Al-Rahimawi watershed is clear evidence that it is characterized by a long perimeter concerning its area. It also passes through an intermediate phase of the river erosion cycle, asymmetry in shape, and increased perimeter curvature. The high lemniscate value of the Al-Rahimawi watershed indicates that it is in the early stages of the erosion cycle, and this is a result of the influence of the rock quality and the structural conditions of the area, as well as the effects of the climate. Al-Rahimawi watershed has a high length-to-width ratio, suggesting it is nearly rectangular. This indicates the Al-Rahimawi watershed is still in the middle of the river erosion cycle, and the high value of this parameter indicates that this phase may last for a considerable amount of time given the current drought circumstances.

ACKNOWLEDGEMENTS

The author would like to acknowledge the scientific support offered by the Babylon Center for Civilization and Historical Studies, University of Babylon.

CONFLICT OF INTEREST STATEMENT

The author declares that there are no conflicts of interest regarding the publication of thismanuscript.

LITERATURE CITED

Agha, O. M. A. M. and Şarlak, N. 2016. Spatial and temporal patterns of climate variables in Iraq. *Arabian Journal of Geosciences*, 9(4): 301-311. [CrossRef]

Ahmed, H. G., Issa, M. J., and Ali, J. H. 2022. Study of limestones from the Nfayil formation in Bahr Al-Najaf depression and suitability for thermal conductivity. *Iraqi Journal of Science*, 63(7): 2980-2986. [CrossRef]

Al-Jiburi, H. K. and Al-Basrawi, N. H. 2009. Hydrogeology. *In*: Geology of Iraqi Southern Desert. *Iraqi Bulletin of Geology and Mining*, Special Issue, 2: 77 - 91.

Al-Jiburi, H. K. and Al-Basrawi, N. H. 2015. Hydrogeological map of Iraq, scale 1: 1000 000, 2013. *Iraqi Bulletin of Geology and Mining*, 11(1): 17-26.

Al-Jiburi, H. K. and Al-Basrawi, N. H. 2015. Tectonic map of Iraq, Scale 1: 1000 000, 3rd EDITION, 2012. *Iraqi Bulletin of Geology and Mining*, 11(1): 17-26.

Banerjee, A., Singh, P. and Pratap, K. 2017. Morphometric evaluation of Swarnrekha watershed, Madhya Pradesh, India: an integrated GIS-based approach. *Applied Water Science*, 7(4): 1807-1815. [CrossRef]

Chorley, R. J., Malm, D. E. G. and Pogorzelski, H. A. 1957. A new standard for estimating drainage basin shape. *American Journal of Science*, 255(2): 138-141. [CrossRef]

Das, S. and Pardeshi, S. D. 2018. Morphometric analysis of Vaitarna and Ulhas River basins, Maharashtra, India: using geospatial techniques. *Applied Water Science*, 8: 158 [CrossRef]

Dinagara, P., Thena, T., Nirmal, B., Aswathy, M. R., Saravanan, K. and Mohan, K. 2017. Morphometric analyses of Neyyar River Basin, southern Kerala, India. *Geology, Ecology, and Landscapes*, 1(4): 249-256. [CrossRef]

Fenta, A. A., Yasuda, H., Shimizu, K., Haregeweyn, N. and Woldearegay, K. 2017. Quantitative analysis and implications of drainage morphometry of the Agula watershed in the semi-arid northern Ethiopia. *Applied Water Science*, 7(7): 3825-3840. [CrossRef]

Fouad, S. F. A. 2015. Tectonic Map of Iraq, Scale 1: 1000 000, *Iraqi Bulletin of Geology and Mining*, 11(1): 1-7. [ResearchGate]

Gajbhiye, S., Mishra, S. K. and Pandey, A. 2014. Prioritizing erosion-prone area through morphometric analysis: an RS and GIS perspective. *Applied Water Science*, 4(1): 51-61. [CrossRef]

Höfle, B., Griesbaum, L. and Forbriger, M. 2013. GIS-Based detection of gullies in terrestrial lidar data of the cerro llamoca peatland (peru). *Remote Sensing*, 5(11): 5851-5870. [CrossRef]

Horton, R. E. 1945. Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative morphology. *Bulletin of the Geological Society of America*, 56(3): 275-370. [CrossRef]

Jassim, R. Z. 2009. Mineral resources and occurrences of Iraqi Southern Desert. *Iraqi Bulletin of Geology and Mining*, Special issue: 93-107.

Jassim, S. Z. and Goff, J. C. 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, 341pp.

Rai, P. K., Mishra, V. N. and Mohan, K. 2017. A study of morphometric evaluation of the Son basin, India using geospatial approach. *Remote Sensing Applications: Society and Environment*, 7: 9-20. [CrossRef]

Li, X., Cheng, G., Lin, H., Cai, X., Fang, M., Ge, Y., Hu, X., Chen, M. and Li, W. 2018. Watershed system model: the essentials to model complex human-nature system at the River Basin Scale. *Journal of Geophysical Research: Atmospheres*, 123(6): 3019-3034. [CrossRef]

Lombana, L., and Martínez-Graña, A. 2021. Multiscale hydrogeomorphometric analysis for fluvial risk management. Application in the Carrión River, Spain. *Remote Sensing*, 13(15): 2955. [CrossRef]

Ma'ala, K. A. 2009. Geomorphology. *In*: Geology of Iraqi Southern Desert. *Iraqi Bulletin of Geology and Mining*, Special Issue, 2: 9-27.

Maaroof, B. F. 2022a. Geomorphometric assessment of the river drainage network at Al-Shakak basin (Iraq). *Journal of the Geographical Institute Jovan Cvijic SASA*, 72(1): 1-13. [CrossRef]

Maaroof, B. F. 2022b. Geomorphological assessment using geoinformatics applications of the sloping system of Al-Ashaali drainage basin at Iraqi Southern Desert. *Iraqi National Journal of Earth Science*, 22(1): 38-54. [CrossRef]

Maaroof, B. F., Al-Abdan, R. H. and Kareem, H. H. 2021. Geographical assessment of natural resources at Abu-Hadair drainage basin in Al-Salman Desert. *Indian Journal of Ecology*, 48(3):797-802. [Click here]

Maaroof, B. F. and Kareem, H. H. 2020. Water erosion of the slopes of Tayyar drainage basin in the desert of Muthanna in Southern Iraq. *Indian Journal of Ecology*, 47(3): 638-644. [Click here]

Maaroof, B. F. and Kareem, H. H. 2022. Geomorphometric analysis of Al-Teeb River meanders between Al-Sharhani basin and Al-Sanaf Marsh, eastern of Misan Governorate, Iraq. *Misan Journal of Academic Studies*, 42(1): 441- 455. [CrossRef]

Maaroof, B., Omran, M., Al-Qaim, F., Salman, J., Hussain, B., Abdellatif, M., Carnacina, I., Al-Hasani, B., Jawad, M. and Hussein, W. 2023. Environmental assessment of Al-Hillah River pollution at Babil Governorate (Iraq). *Journal of the Geographical Institute Jovan Cvijic*, *SASA*, 73(1): 1-16. [CrossRef]

Magesh, N. S., Jitheshlal, K. V., Chandrasekar, N. and Jini, K. V. 2012. GIS based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats, Thrissur District, Kerala, India. *Earth Science Informatics*, 5(2): 111-121. [CrossRef]

Maxwell, A. E. and Shobe, C. M. 2022. Land-surface parameters for spatial predictive mapping and modeling. In *Earth-Science Reviews* 226(103): 1-22. [CrossRef]

Miletic, P. 1963. An outline of the geology and hydrogeology of the southern desert area of Iraq. *Geoloski Vjesnik*, *Zagreb*, 15: 369-390.

Miller, V. C. 1953. A Quantitative Geomorphic Study of drainage basin characteristics in the Clinch Mountain Area, Virginia and Tennessee. Department of Geology Columbia University, New York, p. 389-402.

Resmi, M. R., Babeesh, C. and Achyuthan, H. 2019. Quantitative analysis of the drainage and morphometric characteristics of the Palar River basin, Southern Peninsular India; using BAD calculator (bearing azimuth and drainage) and GIS. *Geology*, *Ecology*, *and Landscapes*, 3(4): 295-307. [CrossRef]

Prakash, K., Rawat, D., Singh, S., Chaubey, K., Kanhaiya, S. and Mohanty, T. 2019. Morphometric analysis using SRTM and GIS in synergy with depiction: a case study of the Karmanasa River basin, north central India. *Applied Water Science*, 9, 13. [CrossRef]

Prasannakumar, V., Shiny, R., Geetha, N. and Vijith, H. 2011. Applicability of SRTM data for landform characterization and geomorphometry: A comparison with contour-derived parameters. *International Journal of Digital Earth*, 4(5): 387-401. [CrossRef]

Rai, P. K., Chandel, R. S., Mishra, V. N. and Singh, P. 2018. Hydrological inferences through morphometric analysis of lower Kosi River basin of India for water resource management based on remote sensing data. *Applied Water Science*, 8: 15. [CrossRef]

Rai, P. K., Mohan, K., Mishra, S., Ahmad, A. and Mishra, V. N. 2017. A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. *Applied Water Science*, 7: 217-232. [CrossRef]

Salman, S. A., Shahid, S., Ismail, T., Chung, E. S. and Al-Abadi, A. M. 2017. Long-term trends in daily temperature extremes in Iraq. *Atmospheric Research*, 198: 97-107. [CrossRef]

Schumm, S. A. 1963. Sinuosity of alluvial rivers on the Great Plains. *Geological Society of America Bulletin*, 74(9): 1089-1100.

Soni, S. 2017. Assessment of morphometric characteristics of Chakrar watershed in Madhya Pradesh India using geospatial technique. *Applied Water Science* 7(5): 2089-2102. [CrossRef]

Sreedevi, P. D., Sreekanth, P. D., Khan, H. H., and Ahmed, S. 2013. Drainage morphometry and its influence on hydrology in a semi-arid region: Using SRTM data and GIS. *Environmental Earth Sciences*, 70(2): 839-848. [CrossRef]

Strahler, A. N. 1957. Quantitative Analysis of Watershed Geomorphology. *Transactions, American Geophysical Union*, 38(6): 913-920.

Strahler, A. N. 2010. Statistical analysis in geomorphic research. *Most*, 58(1): 2-22.

Yadav, S. K., Singh, S. K., Gupta, M., and Srivastava, P. K. 2014. Morphometric analysis of Upper Tons basin from Northern Foreland of Peninsular India using CARTOSAT satellite and GIS. *Geocarto International*, 29(8): 895-914. [CrossRef]

BULLETIN OF THE IRAQ NATURAL HISTORY MUSEUM

Bull. Iraq nat. Hist. Mus.
(2024) 18 (2): 277 - 295.

التحليل الكمي باستخدام النمذجة الجيومكانية للخصائص الشكلية لمستجمع مياه الرهيماوي في صحراء العراق الجنوبية

بشار فؤاد معروف

مركز بابل للدراسات الحضارية والتاريخية، جامعة بابل، العراق

الاستلام: 2024/2/3، المراجعة: 2024/5/25، القبول: 2024/5/29، تأريخ النشر: 2024/12/20

الخلاصة

تضمن هذا البحث دراسة حوض تصريف الرهيماوي، وهو أحد مستجمعات المياه في صحراء العراق الجنوبية. يمثل هذا الحوض أحد الأنظمة الهيدروجيومورفولوجية ضمن منطقة الوديان السفلى، حسب التقسيم الجيومورفولوجي للعراق. وُظِفَت مجموعة من المعايير الجيومورفولوجية للصفات المورفولوجية لمستجمع مياه الرهيماوي التي أعطت نتائج واضحة حول السمات الجيومورفولوجية ومرحلة التعرية لهذا الحوض. المعاملات الجيومورفومترية المستخدمة في هذه الدراسة هي نسبة الاستدارة(Rc) ، ومعامل الشكل (Ff)، ونسبة الاستطالة(Re) ، ومعامل الاندماج(Cc) ، ونسبة الانبعاج(k) ، ونسبة الطول/ العرض(R / W). إضافة إلى استخدام نموذج الارتفاع الرقمي (DEM) نوع SRTM والصورة الفضائية للقمر الصناعي الأمريكي Landsat ETM+8. أشارت النتائج إلى أن نسبة الاستدارة كانت 0.154 مما يدل على أن مستجمع المياه ابتعد عن الشكل الدائري. كما أن قيمة عامل الشكل كانت منخفضة حيث وصلت إلى 0.098 مما يدل على أن مستجمع المياه قريب من الشكل المثلثي. كما أشارت النتائج إلى أن نسبة الاستطالة كانت منخفضة حيث بلغت 0.353، وهذه القيمة تشير إلى أن المستجمع قريب من الشكل المستطيل. كما أن قيمة معامل الاندماج كانت مرتفعة حيث بلغت 2.415. وهناك ارتفاع في نسبة الانبعاج بقيمة 2.551 مما يدل على التقدم في مراحل دورة التعرية. أشارت النتائج إلى أن نسبة الطول إلى العرض بلغت 5.054 وهي نسبة مرتفعة.