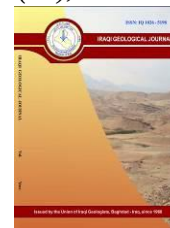




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Morphometric Analysis and Hydrological Potential of the Al-Bu Faraj Basin, Southwest of Tharthar Lake, Western Iraq

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Abstract

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The Al-Bu Faraj basin, a semi-arid catchment southwest of Tharthar Lake, western Iraq, This basin is located within a semi-arid environment and covers an area of 583 km² in Anbar Governorate, western Iraq. The study relied on a combination of remote sensing techniques and geographic information systems, drawing on multiple datasets. The study aims to identify the characteristics of the basin by studying and analyzing the approved data. The total length of the basin's course was about 645.95 km, with a topography of about 61 m, and the terrain ratio is about 0.00174. Using a 30 m spatial-resolution Shuttle Radar Topography Mission Digital Elevation Model and GIS-based hydrological tools. Based on the results of the shape factor 0.310, elongation ratio 0.354, and roundness ratio 0.192, it was found that the basin has a rectangular shape, which reflects the occurrence of peak drainage over a long period of time, which means that there are low chances of a sudden flood occurring. It also reflects the basin's ability to drain water well, but not its ability to absorb it. The study results indicate that the basin is mostly flat, with a good drainage system that produces surface runoff, as shown by a combination of linear, areal, and relief scales. The research findings are useful for watershed management, as well as for measuring the impact of floods, the way water moves over the surface, and the amount of rainwater collected within other semi-arid basins.

Keywords: Morphometric analysis; GIS; Remote sensing; Al-Bu Faraj basin characteristics; Arid regions; Western Iraq

1. Introduction

Water scarcity and the increasing variability of water resources represent major challenges for sustainable development in arid and semi-arid regions, particularly in Iraq, where water availability is affected by climatic fluctuations and increasing demand (Central Statistical Organization, 2021). At the drainage-basin scale, understanding surface runoff, infiltration potential, drainage development, and erosion tendency is essential for improving water-resource assessment and watershed management (Strahler, 1957). Morphometric analysis provides a quantitative method for evaluating the geometry, drainage-network characteristics, and relief properties of a basin, which are directly related to its hydrological response (Horton, 1945). Parameters such as drainage density, stream frequency, elongation ratio, circularity ratio, basin relief, and slope are commonly used to interpret runoff behavior, flood response, groundwater-recharge potential, and erosion susceptibility (Singh et al., 2024). In

geomorphological and geological studies, remote sensing has become an essential tool for geological applications (Bety, 2022). Recent studies have also shown that GIS-based morphometric analysis is particularly useful in arid and semi-arid basins where hydrological field data are limited and spatial assessment is required for water-resource planning (Yadav et al., 2014). Therefore, integrating morphometric analysis with remote sensing and GIS provides a practical scientific basis for identifying runoff concentration, infiltration zones, erosion-prone areas, and potential sites for water harvesting.

The Al-Bu Faraj Basin, located about 40 km southwest of Tharthar Lake in Al-Anbar Governorate, represents an important drainage basin within the western part of Iraq, where limited rainfall, high evaporation, and irregular runoff increase the need for detailed hydrological evaluation. Despite its location near the Tharthar system, the basin has received limited detailed morphometric and hydrological investigation, which restricts the understanding of its drainage behavior, runoff potential, and suitability for water-harvesting or groundwater-recharge planning. The main aim of this study is to conduct an integrated morphometric analysis of the Al-Bu Faraj Basin using remote sensing data and GIS techniques in order to evaluate its hydrological characteristics and their implications for sustainable water-resource management. The first objective is to delineate the basin and drainage network and calculate the main linear, areal, and relief morphometric parameters using DEM-based GIS analysis. The second objective is to interpret the hydrological significance of these parameters in relation to surface runoff, infiltration, erosion tendency, and groundwater-recharge potential within the study area. The results also can aid in guiding the water-harvesting planning, groundwater-recharge efforts, as well as watershed management in the southwestern Tharthar area.

2. Geographic Location and Geological Setting of the Study Area

The studied area was located at the southwest of Tharthar Lake, belongs to Al-Anbar Governorate. Geographically, it is positioned between latitude coordinates 33°27'00" N and 33°42'00" N, and longitude coordinates 43°04'0.0"E and 43°27'00"E. The elevation of the basin ranges from 40 to 117 m, according to the DEM. The highlands are located within the northwestern parts, with semi-sloping terrain towards the southeast. Tectonically, the study area is active and affected by regional faulting along with fracture systems extending from the northwest to the southeast. These systems are part of the larger Najd fault system (Sissakian and Fouad, 2012), and this location has a tremendous influence on the shape and orientation of the drainage network, as evidenced by the fact that the main sewer channels line up with the main fault directions. Tectonically, the fundamental framework of the stratigraphy and structure of the study area is influenced by the positioning of Iraq within the tectonic units of Iraq (Bety, 2022). These fracture zones also make a secondary permeability, that leads to more water loss through deep seepage and better paths for groundwater recharge. The Al-Bu Faraj basin has a total area of approximately 583 km², a maximum length of about 35 km, a maximum width of 22.77 km, and a perimeter of approximately 195 km (Fig. 1). These dimensions, together with the geological and climatic features mentioned above, makes a physical framework for the detailed morphometric analysis that will be done in the next sections.

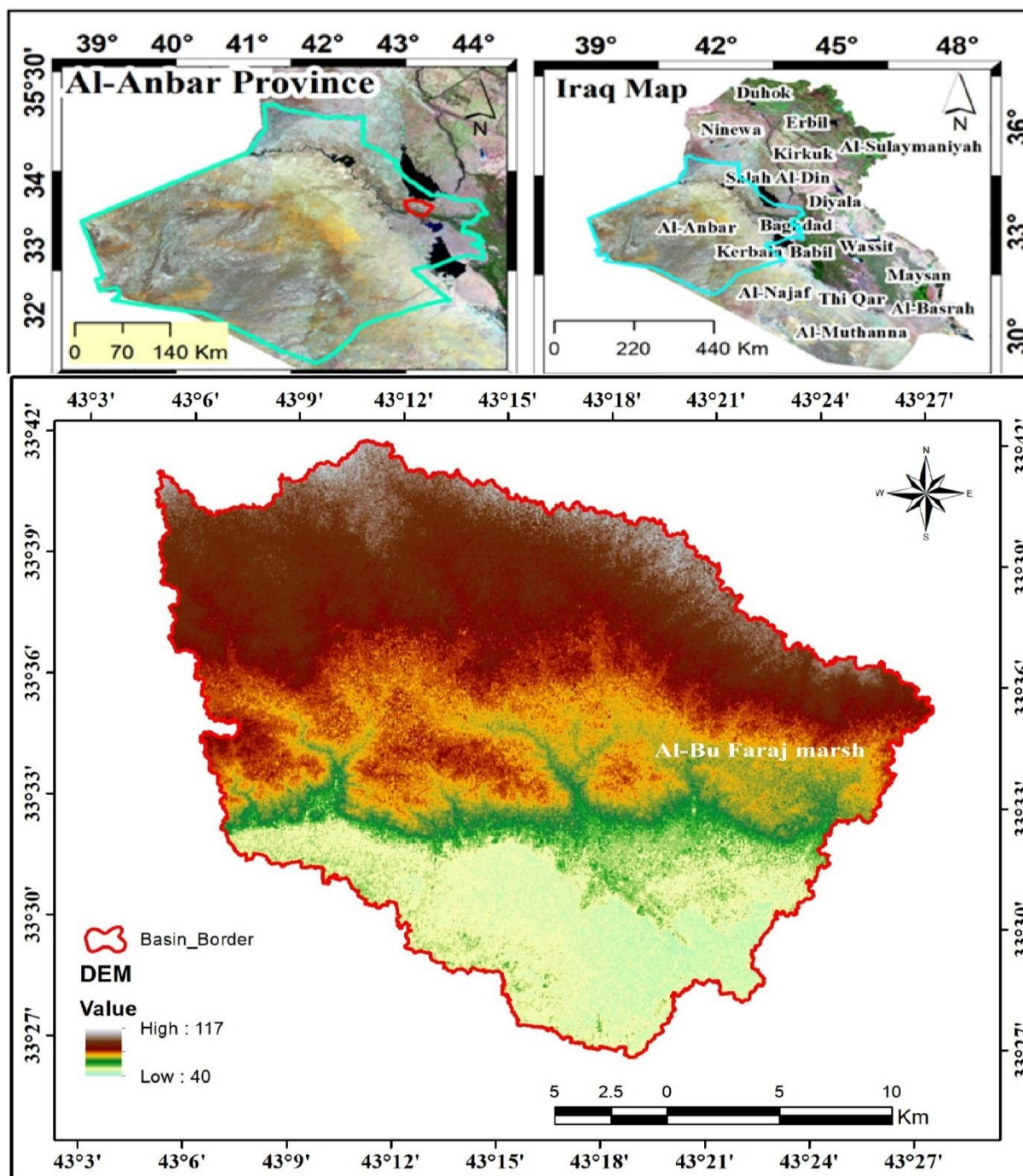


Fig. 1. Location map of the study area with the 30 m SRTM DEM background (USGS, 2013)

From a geological perspective, the basin is situated within a somewhat intricate geological framework. The geological map of the study area (Fig. 2) shows that the rocks that are exposed in the study area are mostly from the Middle Miocene Fatha Formation and the Late Miocene Injana Formation. There is also a layer of Quaternary sediments on top of them (Jassim and Goff, 2006).

The exposed geological units within the study area mainly include the Injana Formation, Nfayil Formation, river-terrace deposits, gypcrete deposits, and floodplain deposits, as compiled and modified from the Geological Map of Iraq (Sissakian and Fouad, 2012). The Injana Formation is dominated by sandstone, siltstone, and claystone, whereas the Nfayil Formation and Quaternary deposits include carbonate, marl, claystone, evaporitic, terrace, gypcrete, and floodplain sediments. Differences within

the lithological influence runoff along with the infiltration by the affecting of permeability, drainage patterns, along with the groundwater-recharge potential (Jassim and Goff, 2006).

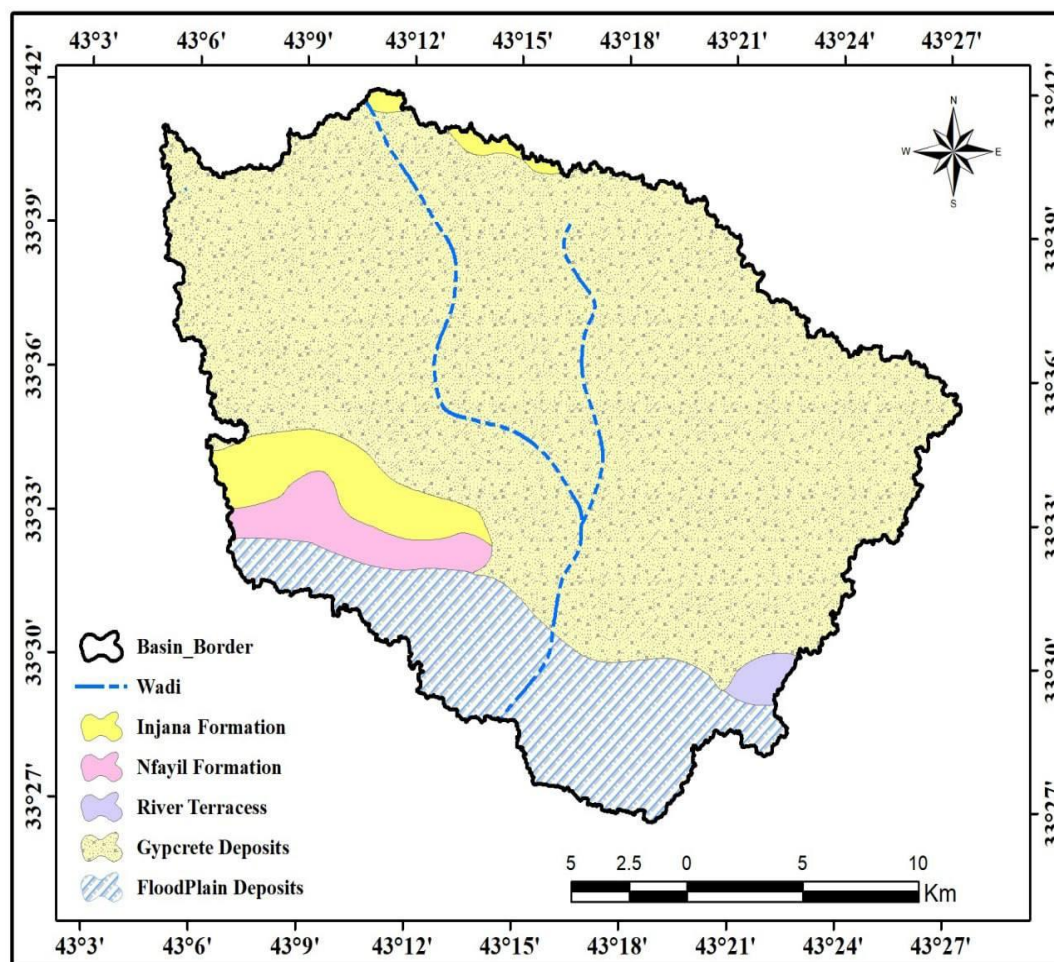


Fig. 2. Geological map of the studied basin (Sissakian and Fouad, 2012)

3. Materials and Methods

Both remote sensing and GIS datasets were used for analyzing the morphometric characteristics of the Al-Bu Faraj Basin. Similar integrated approaches have been applied in Iraqi environmental studies, including land-use as well as the land-cover analysis within the southern Mesopotamian Plain (Ahmed and Al-Samarrai, 2015). The data were processed using the GIS-based tools to derive also to interpret the basin's morphometric parameters with greater spatial consistency as well as reliability (Table 1).

The methodological workflow adopted in this study is summarized in Fig. 3. The analysis started with the collection of the main spatial datasets, including the 30 m Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM), Landsat 8 imagery, and geological and structural maps. The DEM was preprocessed by filling sinks, followed by flow-direction and flow-accumulation analysis to extract the drainage network. The basin and sub-basin boundaries were then delineated, and the extracted streams were ordered according to Strahler's method. The morphometric parameters were calculated and grouped into linear, areal, and relief aspects. Finally, the results were integrated with geological and interpreted lineament data to support the hydrological interpretation and water-resources management assessment. Landsat 8 OLI/TIRS imagery acquired on 19 April 2025, with Path/Row 169/037, was used for visual verification and spatial interpretation. Bands 4, 5, and 10 were used to support the interpretation of drainage and lineament features.

Table 1. Sources and Specifications of the Main Data Used in the Study

Data Type	Source	Resolution/Specifications	Main Purpose
Digital Elevation Model (DEM)	USGS – SRTM Data	m30 Spatial Resolution	Basis for Extracting Topographic and Hydrographic Features
Satellite Imagery	Landsat 8 OLI/TIRS	30 m Spatial Resolution (Multispectral Bands)	Visual Verification, Data Interpretation, and Spatial Analysis Support
Geological Data	Iraqi Geological Survey	Geological and Structural Maps	Interpretation of the Geological Background Affecting Basin Shape

The Al-Bu Faraj Basin lies within the arid-to-semi-arid climatic zone of western Iraq, where rainfall is generally limited, irregular, and concentrated mainly during the wet season. The basin's climate was characterized by a short, seasonal rainfall events, a long dry period, as well as a high evaporation. These conditions are indeed promote intermittent surface runoff, while limiting sustained infiltration along with the groundwater recharge. Due to the lack of long-term local rain-gauge records, the climatic assessment is based on the regional data as well as NASA POWER records for the last two decades.

4. Results

4.1. Processing a Digital Elevation Model (DEM) and Finding Hydrographic Features

The SRTM DEM with 30 m spatial resolution was processed in ArcGIS to extract the hydrographic and morphometric features of the Al-Bu Faraj Basin. The DEM was first corrected using the Fill tool, and the drainage network was then derived using the D8 flow-direction algorithm and flow-accumulation analysis, following the approach of O'Callaghan and Mark (1984). The extracted streams were ordered according to Strahler's stream-ordering system, while the basin and sub-basin boundaries, slope, and elevation statistics were calculated from the processed DEM for subsequent morphometric analysis (Strahler, 1957). Slope was calculated from the processed DEM using the ArcGIS Slope tool and summarized for each sub-basin using zonal statistics, together with elevation minimum, maximum, and standard deviation values (Figs. 4 and 5, Table 2).

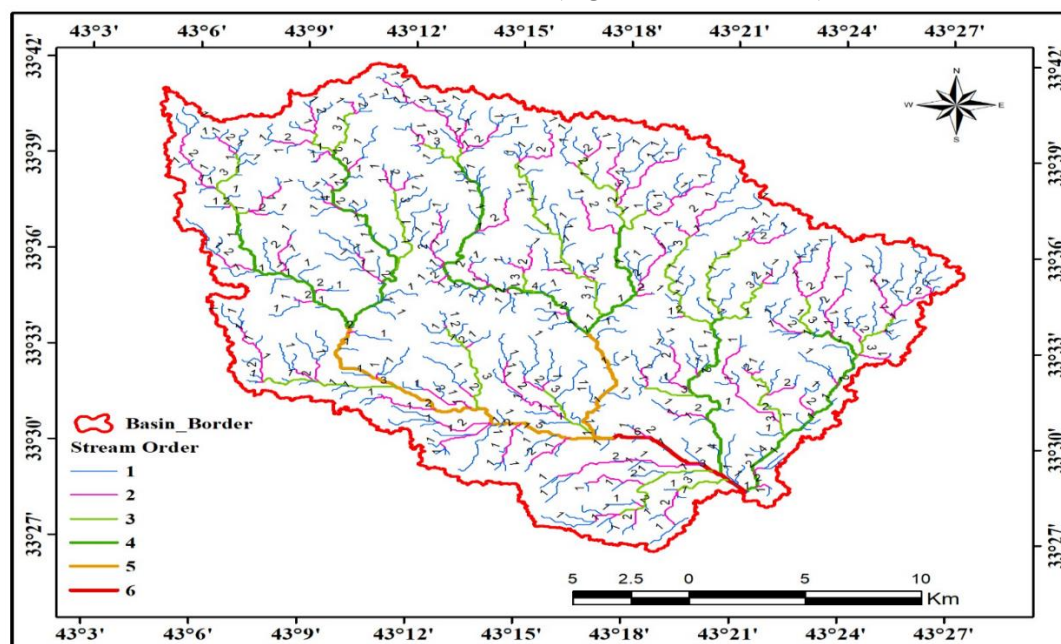


Fig. 3. Stream-order map of the Al-Bu Faraj Basin derived from the 30 m SRTM DEM and classified according to Strahler's stream-ordering system

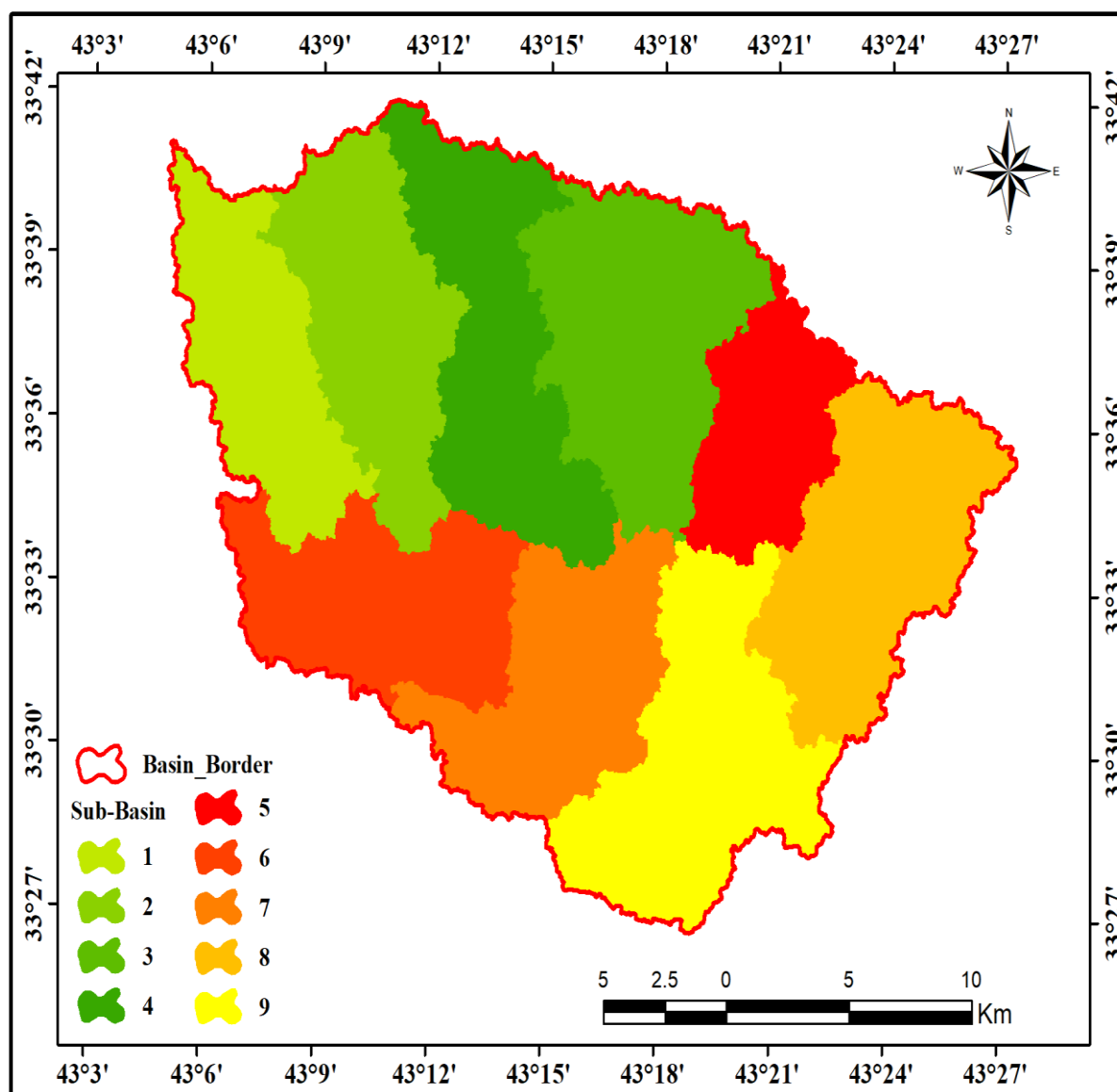


Fig. 4. Sub-Basins of the area extracted from the DEM (30 M) resolution

Table 2. Morphometric Characteristics of the Nine Sub-Basins Delineated within the Al-Bu Faraj Basin

Sub-basin	Area (km ²)	Slope (°)	Elevation Min (m)	Elevation Max (m)	Elevation Standard Deviation (SD)
1	55.004	4.144518	63	114	7.514945
2	62.753	4.208371	65	114	8.710211
3	76.692	4.320723	63	117	9.89661
4	71.225	4.268586	60	115	10.237
5	40.386	4.224872	61	110	10.47357
6	61.364	3.717072	42	88	10.51373
7	61.853	3.440918	44	85	8.480054
8	73.479	4.190641	44	108	14.21885
9	79.285	3.976179	40	83	6.487414

The nine sub-basins range in area from 40.39 km² (Sub-basin 5) to 79.285 km² (Sub-basin 9), with slopes varying between 3.44° and 4.32°. The elevation standard deviation (SD) values indicate the

degree of topographic heterogeneity within each sub-basin, with Sub-basin 8 showing the highest topographic variation (SD = 14.22 m) and Sub-basin 9 the lowest (SD = 6.49 m).

4.2. Morphometric Analysis

The morphometric characteristics of the Al-Bu Faraj Basin and its sub-basins were calculated using ArcGIS tools, including Map Algebra, Field Calculator, and zonal statistics. The adopted parameters were grouped into three main categories: linear aspects, areal aspects, and relief aspects. These parameters were selected because they provide quantitative information on drainage-network development, basin geometry, surface runoff, infiltration potential, and topographic variation.

4.2.1. Linear aspects

The linear aspects describe the organization and development of the drainage network. In this study, stream order, stream length, and bifurcation ratio were derived from the extracted drainage network. Stream ordering was carried out according to Strahler's method, in which first-order streams represent the smallest unbranched channels, and the order increases only when two streams of the same order join (Strahler, 1957).

The bifurcation ratio (Rb) expresses the relationship between the number of stream segments of a given order and those of the next higher order. It was calculated according to Schumm (1956) using the following equation:

$$Rb = N_u / N_{u+1} \quad (1)$$

where Rb is the bifurcation ratio, N_u is the number of stream segments of order u , and N_{u+1} is the number of stream segments of the next higher order.

4.2.2. Areal aspects

The Areal parameters describes the basin geometry along with its influence on the runoff, infiltration, as well as the drainage development. They includes the basin area, perimeter, drainage density, form factor, circularity ratio, along with compactness constant.

The Drainage density (Dd) was calculated by the dividing the total stream length by the basin area. It reflects the degree of drainage development as well as it is influenced by the lithology, permeability, vegetation cover, slope, as well as the runoff conditions (Horton, 1945). It is calculated by using the following equation:

$$Dd = \Sigma L_u / A \quad (2)$$

where Dd was a the drainage density (km/km²), ΣL_u are the total stream length (km), also A was the basin area (km²).

The form factor (Ff) represents the ratio of basin area to the square of basin's length. It can describes the basin's shape along with its effect on the runoff response; lower values indicate a more elongated basin, while higher values indicates a more circular form (Horton, 1945). It is calculated using the following equation:

$$Ff = A / L_b^2 \quad (3)$$

where Ff is the form factor, A represents the basin area (km²), also L_b is the maximum basin length (km). The circularity ratio (Rc) measures how closely the basin resembles a circle. Lower values indicate a more elongated or irregular basin shape (Miller, 1953). It is also calculated using the following equation:

$$Rc = 4\pi A / P^2 \quad (4)$$

where R_c is the circularity ratio, A is the basin area in km^2 , P is the basin perimeter in km, and π is 3.1416.

The compactness constant (C_c) compares the basin perimeter with the circumference of a circle having the same area as the basin. The value that is close to 1 indicates a nearly circular basin, whereas larger values reflect greater deviation from circularity (Strahler, 1964). It was calculated using the following equation:

$$C_c = P / 2\sqrt{\pi A} \quad (5)$$

where C_c is the compactness constant, P is the basin perimeter in km, A is the basin area in km^2 , and π is 3.1416.

4.2.3. Relief aspects

Relief aspects describe the vertical characteristics of the basin and their influence on runoff velocity, erosion intensity, and topographic variation. In this study, minimum elevation, maximum elevation, elevation standard deviation, and slope were extracted from the processed 30 m SRTM DEM. The slope was derived using the ArcGIS Slope tool also summarized for each sub-basin using zonal statistics. The elevation standard deviation were also calculated to indicate topographic variability.

The selected morphometric parameters represent the main factors controlling the basin response, including drainage development, basin shape, runoff, infiltration, slope, as well as the relief.

The morphometrical results are interpreted alongside the geological map, to examine the influence of lithology as well as the permeability on the basin development along with the spatial variation within the basin.

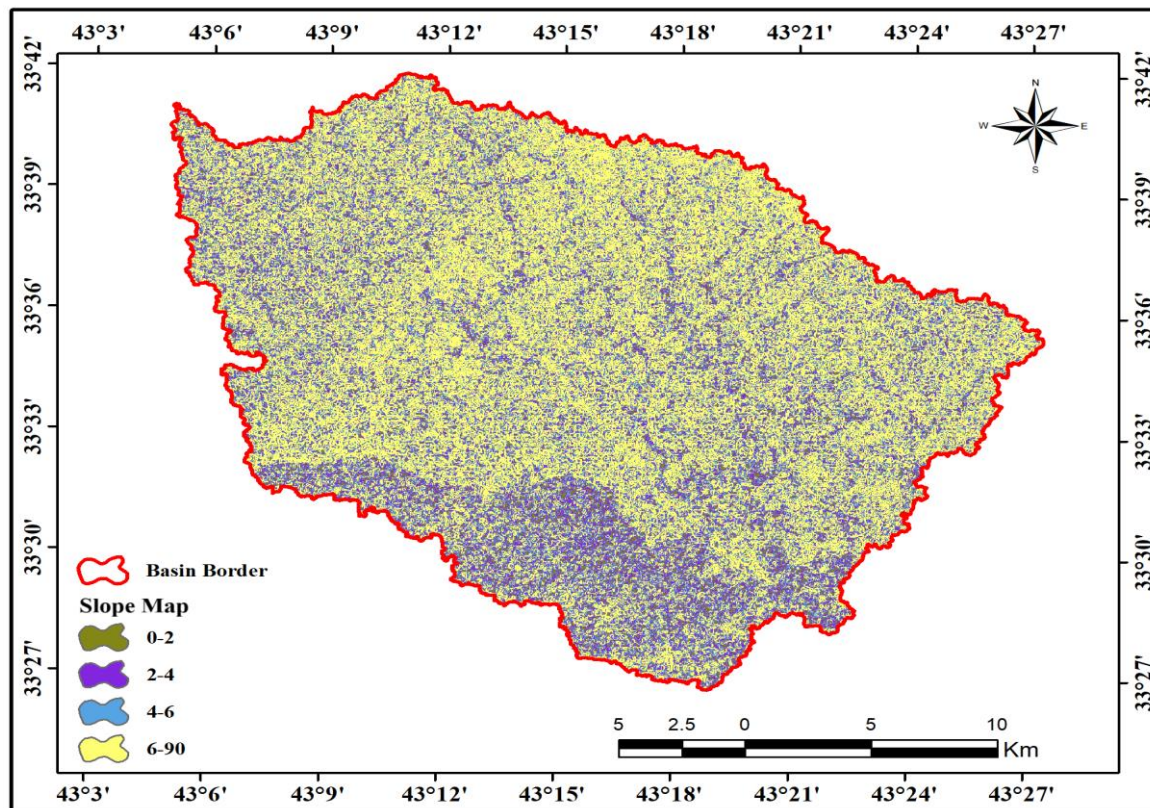


Fig. 5. Slope map of the Al-Bu Faraj Basin derived from the 30 m SRTM DEM and classified according to FAO slope-gradient classes

To support the interpretation of the morphometric results, drainage-density as well as the stream-order maps in which compared with the geological map. This comparison aid in assess how lithology along with permeability may influence drainage patterns, runoff, infiltration, as well as the local drainage development within the Al-Bu Faraj Basin.

4.2.4. Verification of morphometric results

Because of the field measurements as well as the discharge records were unavailable, the morphometrical results were verified through an indirect spatial comparison. The basin boundary, drainage network, sub-basins, slope, as well as the elevation parameters are checked against the 30 m SRTM DEM, Landsat 8 OLI/TIRS imagery, as well as the GEOSURV geological maps. The extracted streams are visually compared with satellite imagery along with the terrain lows to confirm their spatial accuracy. Although this approach does not replace the field or the hydrological validation, it provides a reasonable verification method for the data-limited basin.

4.3. Basic Morphometric Characteristics and Basin Shape

Table 3 summarizes the main geometric as well as the topographic characteristics of the basin derived from the DEM. The total area of the basin, its perimeter, the length of the main flow channel, and the difference in height between the highest and lowest points are all included in this data.

Table 3. Basic Geometric and Topographic Characteristics of the Al-Bu Faraj Basin

Property	Value	Unit
Area (A)	583	km ²
Perimeter (P)	195	km
Maximum Basin Length (Lb)	35	km
Relief (H)	61	m
Total Number of streams (ΣNu)	608	
Total Stream Length (ΣLu)	645.95	km

The basin covers 583 Km² and has a 195-kilometer-long border, which is not straight. The maximum length of 35 km and the total relief of 61 m point to a terrain that is not too steep. There are 608 streams in the drainage network, which are about 646 km long in total. This is what was used to figure out the morphometric indices in Table 4.

Table 4. Morphometric Shape Parameters of the Al-Bu Faraj Basin

Coefficient	Value	Interpretation
Form Factor (Ff)	0.310	Shows a shape that is relatively long and different from wide shapes.
Elongation Ratio (Re)	0.354	This means that the basin is much longer than a round shape.
Circularity Ratio (Rc)	0.192	Shows a basin that isn't perfectly round; it's not a perfect circle.
Compactness Constant (Cc)	2.281	A high value confirms the length of the perimeter in relation to the area of the basin.
Relief Ratio (R_h)	0.00174	

A basin hydrographical network was analyzed according to the Strahler (1957) drainage order system. Table 5 shows the numbers along with lengths for the drains for each drainage order.

Table 5. Stream Order Statistics for the Al-Bu Faraj Basin According to Strahler's (1957) Classification System

Basin Name	Stream order	Number of Streams (N _u)	Total Stream Length (L _u) (km)
Al-Bu Faraj Basin	First-order	466	417.24
	Second-order	110	91.41
	Third-order	23	19.22
	Fourth-order	6	75.85
	Fifth-order	2	34.91
	Sixth-order	1	7.33
Total.		608	645.95

Based on the length and number of drains, the most important drainage network parameters were calculated. Drainage Density (Dd) is equal to 1.108 km/km². This value indicates that the basin has a medium drainage density, which may reflect the influence of moderately permeable rock type or a moderately undulating surface.

Stream Frequency (Fs): The frequency of waterways expresses the number of waterways per unit area, and is calculated as follows (Schumm, 1956):

$$Fs = \Sigma N_u / A \quad (6)$$

Where: Fs = Frequency of waterways (n/km²); N = Total number of waterways in the basin; A = Area of the basin (km²). The Fs is equal to 1.04 Stream/km².

The stream frequency (Fs) was calculated as 1.04 streams/km², indicating a moderate development of drainage channels within the basin. This value does not indicate a structural control alone, but it reflects the combined effects of the lithology, permeability, slope, surface materials, along with the possible structural influences. In areas underlain by less permeable fine-grained or evaporitic units, surface runoff may increase and promote the development of more drainage channels, whereas more permeable or fractured units may enhance infiltration and locally reduce surface drainage density.

Texture Ratio (T): The texture ratio represents the relationship between the number of waterways and the perimeter of the basin, and is used as an indicator of drainage density, and is calculated as follows (Horton, 1945)

$$T = \Sigma N_u / P \quad (7)$$

Where: T = Texture Ratio (n/km); N_u = Total number of waterways; P = Basin perimeter (km). The texture ratio (T) was found to be 3.12 streams/km, which means that the drainage texture is rough. This number shows that there are a lot of lower-order streams compared to the basin perimeter. It also suggests that the drainage network is well-developed in the available topographic units.

4.4. Topographic Characteristics and Sub-Basin Delineation

The ratio of the relief were conducted based on the difference between the basins height (61 m) as well as the length (35 km).

$$R_h = (H/1000)/L_b \quad (8)$$

Where: $H = 61 \text{ m} = 0.061 \text{ km}$, $L_b = 35 \text{ km}$, $R_h = 0.061 / 35 = 0.00174$, $R_h = 0.00174$.

The very low relief ratio (0.00174) confirms that a gently undulating to a nearly flat nature of the basin's topography, the characteristic of this low-relief desert landscapes. this low values typically result in reduced surface runoff velocities along with prolonged concentration times. 3.3. Basic Morphometric Characteristics and Basin Shape

5. Discussion

5.1. Basin Shape and Hydrological Response

The morphometric results indicate that the Al-Bu Faraj basin has an elongated and irregular shape. This is supported by the low form factor ($F_f = 0.310$), elongation ratio ($R_e = 0.354$), and circularity ratio ($R_c = 0.192$), together with the relatively high compactness constant ($C_c = 2.281$). These values show that the basin is far from a circular form and has an irregular perimeter relative to its area. Hydrologically, elongated basins commonly have a longer concentration time and a more delayed runoff response than circular basins, where runoff is more likely to reach the outlet within a shorter period. Therefore, the shape parameters suggest that peak discharge in the Al-Bu Faraj Basin is likely to be less sudden and more distributed over time, especially during seasonal rainfall events.

The compactness constant as well as the circularity ratio indicate an irregular basin shape rather than the direct tectonic control. This geometry may reflect the combined effects of the lithology, erosion, surface materials, as well as the possible structural influences. The basin including both Injana along with Nfayil formations, together with river-terrace, gypcrete, as well as floodplain deposits. Differences in the grain size, permeability, cementation, as well as the erosion resistance affect drainage development, runoff, along with the infiltration. Fine-grained also the evaporitic units generally promote runoff, whereas sandstone as well as the unconsolidated deposits may locally enhance infiltration along with the groundwater recharge.

5.2. Drainage Network Characteristics and Runoff Potential

The Al-Bu Faraj Basin contains about 608 stream segments extending to the sixth order, with a total length of 645.95 km. First-order streams dominate the network, indicating that seasonal runoff was collected through numerous small channels, before reaching higher-order streams. This pattern reflects the combined influence of lithology, slope, drainage density, as well as the surface conditions.

The drainage density ($D_d = 1.108 \text{ km/km}^2$) as well as stream frequency ($F_s = 1.04 \text{ streams/km}^2$) indicating moderate drainage development and seasonal runoff potential. Less permeable fine-grained and evaporitic units may increase surface runoff, whereas more permeable sandy deposits may enhance infiltration. The texture ratio ($T = 3.12 \text{ streams/km}$) reflects a moderately dissected drainage network, while the low relief ratio ($R_h = 0.00174$) along with the gentle slopes suggest relatively slow runoff. Basin response is therefore controlled mainly by rainfall intensity, lithology, permeability, as well as the local drainage concentration.

5.3. Comparison with Similar Semi-Arid Basins

The morphometrical characteristics of the Al-Bu Faraj Basin represents a typical for a semi-arid drainage basin. Its low form factor (0.310), elongation ratio (0.354), as well as the circularity ratio (0.192) indicate an elongated shape as well as a relatively delayed runoff response compared with circular basins. However, the moderate drainage density (1.108 km/km²) also the stream frequency (1.04 streams/km²) shows that the basin has a sufficiently developed drainage network to generate runoff during effective rainfall events.

The very low relief ratio as well as the gentle to moderate slopes, indicating that the basin is neither steep nor highly dissected. Runoff was therefore more strongly influenced by lithology, permeability, surface deposits, also the distribution of lower-order streams than by relief. Overall, the results indicate moderate hydrological potential and provide a preliminary assessment of basin response in a data-limited semi-arid environment.

5.4. Implications for Water-Resources Assessment

The morphometric analysis helps explain the hydrological potential of the Al-Bu Faraj Basin but does not represent a direct water-harvesting suitability assessment. The results indicate that the elongated basin shape may reduce the likelihood of rapid peak discharge, while the moderate drainage density and stream frequency suggest seasonal runoff generation through a moderately developed drainage network. These characteristics are important for identifying general zones of runoff concentration, infiltration potential, and drainage development.

The results may support future water-resources planning by identifying the need for more detailed hydrological and field-based investigations. Any practical selection of water-harvesting structures, recharge sites, or detention-dam locations requires additional datasets, including rainfall-runoff records, soil characteristics, land use/land cover, infiltration measurements, engineering assessment, and field validation. Therefore, the present morphometric analysis should be treated as a preliminary scientific framework that can guide future integrated studies rather than as a final site-selection tool for water-harvesting structures.

5.5. Study Limitations

The main limitation of this study is the reliance on a 30 m SRTM DEM and GIS-based extraction of drainage and morphometric parameters. Although this resolution is suitable for regional morphometric assessment, it may not capture very small drainage channels or subtle local terrain variations. In addition, direct field measurements and observed hydrological discharge data were not available for the basin. The hydrological interpretation was based on the morphometric indicators along with the spatial analysis rather than measured runoff data. Future studies should use higher-resolution DEMs, field validation, rainfall-runoff modeling, as well as soil and infiltration measurements to improve the assessment of basin behavior along with water-resource options.

6. Conclusions

This morphometric analysis of the Al-Bu Faraj Basin reveals a drainage system that are fundamentally controlled by geological structures, which results in a highly elongated basin ($R_e=0.354$) with irregular boundaries ($C_c = 2.281$). The drainage network, comprising 608 streams across six orders, exhibits moderate density ($D_d = 1.108 \text{ km/km}^2$) along with coarse texture ($T=3.12$), reflecting the semi-arid environment as well as the moderate permeability of the Fatha along with Injana formations. The strong alignment between main drainage channels and regional fault systems (trending NW-SE) confirms tectonic control on basin evolution, a finding consistent with the geological

framework of the Western Desert of Iraq. Limitations of this study include the reliance on 30m resolution DEM, which may not capture very fine drainage features, along with the absence of field validation for the extracted drainage network. The findings provide a useful quantitative basis for watershed-management planning, while detailed engineering design and site selection require further field verification and hydrological modeling.

7. Recommendations

Based on the morphometric results and hydrological interpretation of the Al-Bu Faraj Basin, the following recommendations are proposed:

1. Constructing a medium-sized detention dam near the basin outlet may help regulate peak flows and support artificial groundwater recharge, particularly during seasonal runoff events
2. Small check dams may be constructed along selected first- and second-order streams, especially in sub-basins characterized by relatively higher drainage density, in order to reduce runoff velocity, enhance local infiltration, and improve water-harvesting efficiency.
3. Future studies should incorporate higher-resolution DEM data, such as ALOS PALSAR or comparable datasets, together with field surveys to validate the extracted drainage network and refine the morphometric interpretation.
4. Further hydrological modeling using HEC-HMS or similar rainfall–runoff models is recommended to calibrate the morphometric findings with rainfall and runoff data and to improve water-harvesting and watershed-management strategies.

Author contributions: CRediT

Conceptualization: Dr. Mustafa A. Hassan, Dr. Thair Thamer Al-Samarrai, Mays A. Jassam; Data curation, Formal analysis: Mays A. Jassam; Funding acquisition: Not applicable; Investigation: Mays A. Jassam; Methodology: Mays A. Jassam; Project administration, Resources, Software: Mays A. Jassam; Supervision: Dr. Mustafa A. Hassan, Dr. Thair Thamer Al-Samarrai; Validation: Dr. Mustafa A. Hassan, Dr. Thair Thamer Al-Samarrai; Visualization, Writing – original draft: Mays A. Jassam; Writing – review & editing: Dr. Mustafa A. Hassan, Dr. Thair Thamer Al-Samarrai.

Declaration of Competing Interest

No potential conflict of interest relevant to this article was reported.

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Data Availability

Data are available in a public repository.

The data that support the findings of this study are openly available online and found within the references list.

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