Morphometric characteristics and their hydrological Parameters in Targhath Valley basin

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Abstract

Wadi Targhath is one of the significant valleys in western Libya, representing an integrated environmental and geographical system shaped by the interaction of natural and human factors. This study aims to analyze the morphometric and hydrological characteristics of the valley and to assess their impact on local agricultural and economic activities. The research employs spatial analysis methods using Geographic Information Systems (GIS) and remote sensing to identify slope patterns, soil distribution, and surface runoff zones. The findings indicate that Wadi Targhath exhibits notable geomorphological diversity that directly influences land use patterns, while seasonal floods serve as an important water resource that can be utilized to promote sustainable agriculture. The study recommends developing a comprehensive strategy for managing the valley's resources to achieve a balance between economic development and the preservation of the natural environment.

Keywords: Targhath Valley _ Karawa _ Alrasifa _ Garabulli _ Alhawatim.

الخصائص المورفومترية ومدلولاتها الهيدرولوجية لحوض وادي ترغث

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الملخص

يُعدّ وادي ترغث من الأودية المهمة في المنطقة الغربية من ليبيا، إذ يمثل نظاماً بيئياً وجغرافياً متكاملاً تتداخل فيه العوامل الطبيعية والبشرية. تهدف هذه الدراسة إلى تحليل الخصائص المورفومترية والهيدرولوجية للوادي، وتقييم تأثيرها في الأنشطة الزراعية والاقتصادية المحلية. اعتمدت الدراسة على منهج التحليل المكاني باستخدام نظم المعلومات الجغرافية (GIS) والاستشعار عن بعد لتحديد أنماط الانحدار وتوزيع التربة ومناطق الجريان السطحي. أظهرت النتائج أنّ وادي ترغث يتميز بتنوع جيومورفولوجي واضح يؤثر مباشرة في نمط استخدامات الأراضي، كما أن السيول الموسمية تمثل مورداً مائياً مهماً يمكن استثماره في تنمية الزراعة المستدامة. توصي الدراسة بضرورة وضع استراتيجية متكاملة لإدارة موارد الوادي بما يحقق التوازن بين التنمية الاقتصادية والحفاظ على البيئة الطبيعية.

الكلمات المفتاحية: وادي ترغث _ الكراوة _ الرصيفة _ القره بوللي _ الحواتم.

Introduction

Water is one of the most vital natural resources, especially in arid and semi-arid regions where scarcity makes effective management essential. Countries work to utilize all available sources groundwater, surface water, seasonal wadis, and transboundary rivers to support agriculture, store water, and regulate its use. Efficient exploitation of seasonal valleys requires a precise understanding of their morphometric and morphological characteristics and the drainage systems that shape their hydrological behavior. Remote sensing and Geographic Information Systems (GIS), combined with quantitative analysis, offer powerful tools for extracting morphometric variables and interpreting their hydrological, geomorphological, and climatic significance. Such studies play a key role in watershed management and in planning the sustainable use of available resources, strengthening water security and supporting agricultural and economic development. Their importance has grown in light of increasing climate-related challenges, including extreme events such as the 2023 Derna floods and the heavy rainfall in the western region during winter 2024/2025, which altered local wadi characteristics.

The Theoretical Framework of the Study.

1. Research Problem

The study addresses the insufficient understanding of the Targhath Valley Basin's morphometric and hydrological characteristics. The basin's varied terrain—from mountains to plains—and fluctuating rainfall shape its drainage and flood-absorption behavior, yet previous research has not analyzed these factors comprehensively. Hence, the study aims to fill this gap through targeted research questions.

A. What are the morphometric and geomorphological characteristics of the Targhath Valley Basin, and what do they indicate about its topographic and basin structure?
B. In which geomorphological stage (youth – maturity – old age) is the basin currently found, and what evolutionary stages has it undergone?
C. How do the morphometric and geomorphological characteristics influence the drainage system of the Targhath Valley Basin?

2. Hypotheses

A. The morphometric characteristics of the Targhath Valley Basin vary according to the topographic zones (mountainous areas versus plains), which is reflected in the drainage pattern and the behavior of seasonal floods.
B. The geomorphological stage of the Targhath Valley Basin can be identified through the analysis of slope characteristics, stream lengths, and drainage network density, as these indicators reflect the basin's historical development.
C. There is a strong relationship between the morphometric and geomorphological characteristics of the Targhath Valley Basin and their hydrological implications, as these characteristics directly influence surface runoff volume, water discharge rate, and the potential for flood formation.

3. Study Objectives

A. To analyze the morphometric and geomorphological characteristics of the Targhath Valley Basin and determine its topographic diversity.

B. To identify the geomorphological stage of the basin and trace the historical development of its valleys.
C. To examine the impact of morphometric and geomorphological characteristics on the drainage system and surface runoff behavior.
D. To provide scientific and administrative recommendations for managing water resources in the Targhath Valley Basin, aiming to enhance optimal water utilization and reduce flood risks.

4. Significance of the Study

This study is scientifically and practically significant because morphometric and geomorphological characteristics are essential for understanding the behavior of water basins like the Targhath Valley Basin. Scientifically, it helps close the knowledge gap on how topography influences drainage patterns and reveals the geomorphological development stages that shape water distribution and surface runoff. Practically, the study provides a reliable database useful for water and agricultural planning, flood risk management, and sustainable use of seasonal water resources. Its findings support decision-makers and engineers in designing integrated basin-management strategies for arid and semi-arid regions, enhancing water security and promoting local economic development.

5. Research Methodology

This study employs a descriptive-analytical approach to examine the morphometric and geomorphological characteristics of the Targhath Valley Basin and their hydrological implications. It integrates topographic, remote-sensing, and climatic data, then analyzes morphometric indicators such as stream lengths, slopes, and drainage density using GIS tools. The study also investigates landform distribution and the basin s geomorphological evolution. Finally, it links these characteristics to surface-runoff behavior and presents conclusions and recommendations for sustainable water-resource management.

6. Data Sources

Topographic maps at a scale of 1:50,000 issued by the Libyan Survey Department, the Digital Elevation Model (DEM) of the study area with a spatial resolution of 30 meters, scientific books and research studies related to similar topics, and field visits conducted in the study area.

7. Software Used

ArcGIS for analyzing Geographic Information Systems (GIS) data, Excel for facilitating various computational operations, and CorelDRAW X5 for the final production of maps.

8. Previous Studies

A 2025 study by **Mohamed Alkef** analyzed the morphometric characteristics of the Wadi Al-Raml Basin using DEM-based data to assess areal, shape, terrain, and drainage-network features. Using a descriptive and quantitative approach, the study identified key spatial relationships and produced hydrological maps to interpret the basin’s geomorphology. Results showed that the basin covers about 242 km² and extends through three regions mountainous, plain, and a transitional zone between the

Tarhuna Mountains and the coastal plain. The valley's length is roughly 44 km, and its morphometric indicators reveal an elongated shape, reflecting an early erosion stage dominated by headward erosion.

Al-Burki (2023) analyzed the morphometric, hydrological, and drainage-network characteristics of the Targhat Wadi Basin, focusing on how rainfall variability, geological formations, and basin age influence network shape, watercourse density, and the limited use of floodwater. The study found that the basin exhibits rapid flood response, increasing flood risk and complicating the management of seasonal water resources. Its findings align with the current research by emphasizing the role of morphometric features in shaping drainage patterns, controlling runoff behavior, and highlighting the need for sustainable water-resource planning.

Qanaw and Balnur (2022) analyzed the morphometric characteristics of the Wadi Souq Al-Khamis Basin in the Al-Khoms area using Geographic Information Systems (GIS). Their study extracted key topographic, areal, and shape parameters and produced accurate morphometric maps, emphasizing the importance of comprehensive databases for basin analysis. This work intersects with the current research on the Targhath Wadi Basin through its reliance on morphometric indicators to evaluate the drainage network and surface runoff, as well as its use of GIS as the main analytical tool. The two studies differ in some of the formulas used to calculate morphometric characteristics, underscoring the need to adapt methodological approaches to the specific features of each basin to ensure accurate results.

9.Location of the Study Area and Its Geographical Characteristics

The Targhath Wadi, located in northwestern Libya about 70 km east of Tripoli, extends across the eastern Jifarah Plain. It originates from the Tarhuna–Msallata Mountains in the Nafusa range, north of Dawoun, east of Tarhuna city. The basin has two main branches, Wadi Targhath and Wadi Al-Asal, which join near the outlet about 14 km from the plain. The wadi flows 16 km across the Jifarah Plain before reaching the sea at Rasifah. Several secondary tributaries, including Wadi Al-Rwashidiyah, Wadi Al-Khanabah, and Wadi Al-Asal, feed its flow. Covering roughly 268 km², the wadi spans areas such as Western Qasr Akhyar, Al-Rwashidiyah, Al-Hawatim, and Si Ma'mer, with a maximum course length of 49 km and a source-to-outlet distance of 36 km.

Morphometric Characteristics of Wadi Targhath

Morphometric characteristics are among the most important quantitative indicators used in the study of water basins, especially in arid and semi-arid environments, which are characterized by fluctuating rainfall rates and intermittent flow patterns. These characteristics contribute to analyzing the basin's structure, exploring drainage patterns, and assessing environmental risks associated with flash floods. Morphometric characteristics include a set of parameters related to the basin's dimensions, the shape of the drainage network, and its slopes.

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1. Areal Characteristics of the Wadi Targhath Basin

The areal characteristics of dry wadis reflect the nature of arid and semi-arid environments, where the basin's area, shape, and drainage network density contribute to determining the dynamics of surface runoff and the effectiveness of erosion and deposition processes. Understanding these characteristics is essential for interpreting flash flood behavior, guiding water resource management, and assessing geomorphological risks in desert regions.

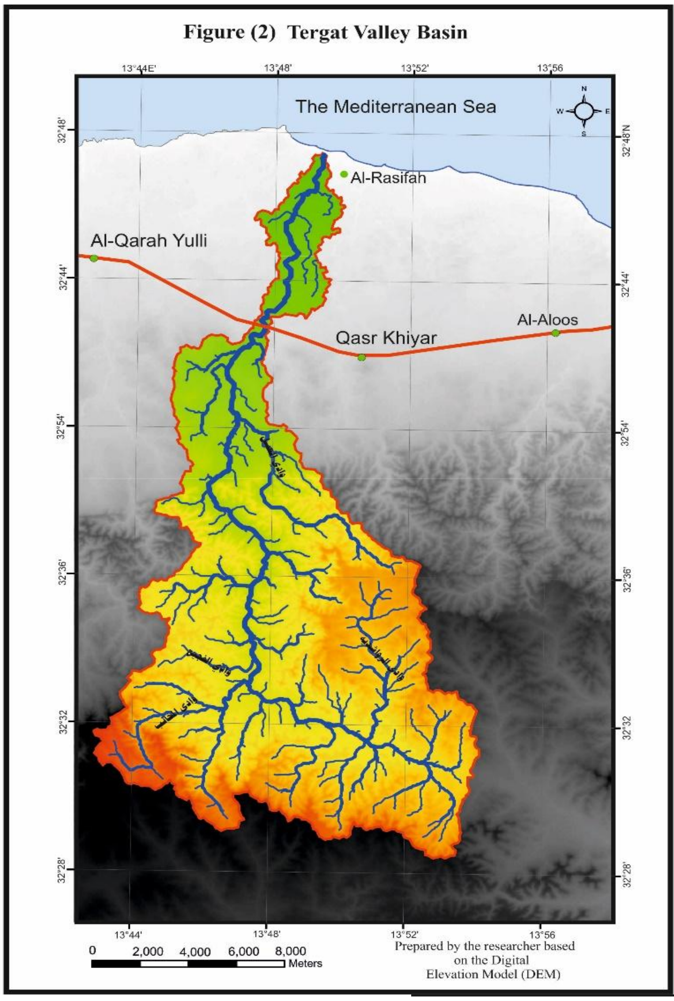
Table (1): Areal Characteristics of the Targhath Wadi Basin

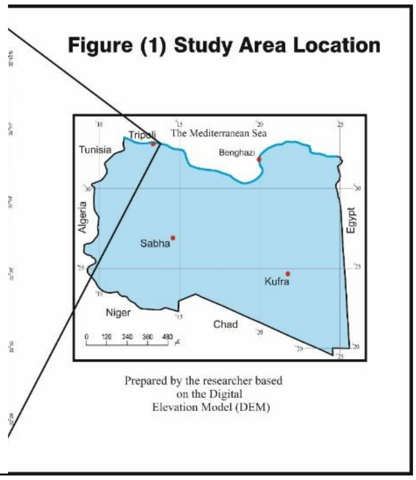
Catchment Area	Basin Length (Source to Outlet)	Basin Length	Basin Perimeter	Basin Width
268 km²	49 km	36 km	127 km	17 km

Source: Prepared by the researcher based on the morphometric analysis of Wadi Targhath.

A. Catchment Area. The catchment area, from which all surface runoff flows toward the main stream, varies in size due to climatic, geological, tectonic, temporal, and human factors. Larger basins generally receive more rainfall, leading to increased erosion, more watercourses, varied sediment transport, and higher discharge. Morphologically, larger basins often have gentler slopes, reflecting a more advanced geomorphological stage, while smaller basins may remain in early stages. (Al-Kaf, 2023). The Targhath Wadi Basin covers 268 km², making it a medium-sized basin, influenced by the proximity of the Msallata Mountains to the coast. (Figure 2).

B. Basin Length. Basin length is a key morphometric variable that reflects the longitudinal distance from the watershed's highest point to its outlet, helping to understand the basin's structure and water discharge behavior. It can be measured using methods such as the





Schumm Method, which draws a straight line from source to outlet to determine general basin length, and the Maxwell Method, which measures along a line parallel to the main channel for a more accurate representation of flow direction, especially in meandering or complex channels. Basin length significantly affects hydrology by influencing runoff velocity and the timing of peak flow. Short basins lead to rapid discharge and higher sediment transport, while long basins slow flow, promoting infiltration and evaporation, thus reducing outflow volume (Al-Dulaimi, 2001).. In the Targhath Wadi Basin, the Schumm Method estimates a basin length of 36 km, with the main channel extending 49 km. This considerable longitudinal extent affects runoff dynamics and enhances infiltration, typical of arid and semi-arid basins. Basin length is therefore essential for understanding geomorphology, drainage behavior, hydrological risks, and guiding water management in regions with sporadic rainfall.

C. Basin Width Basin width is a fundamental morphometric parameter influencing hydrological processes, including surface runoff, infiltration, and evaporation. It is shaped by geological formations and topography and can be measured through various methods, with Digital Elevation Models (DEM) offering the most accurate delineation of basin boundaries and transverse distances. Wider basins, relative to their length, provide greater area for rainfall capture and runoff distribution, reduce flow velocity to enhance sediment deposition, and increase evaporation and transpiration due to the larger exposed surface (Qanaw & Balnoor, 2022). The Targhath Wadi Basin has a width of about 17 km, considered moderate relative to its length. This provides adequate area for rainfall collection, runoff distribution, and infiltration, while affecting water loss through evaporation and transpiration. Basin width is thus a vital morphometric indicator for assessing hydrological balance and guiding water resource management in arid and semi-arid regions with irregular rainfall.

D. Valley Circumference. Valley circumference is the boundary line separating a basin from neighboring basins, following the highest topographic points that direct water to the main channel and outlet. It is a key morphometric indicator for defining basin boundaries and assessing areal structure, typically measured using DEMs or detailed topographic maps. Circumference also informs other morphometric parameters, such as circularity ratio and form factor, linking basin shape to runoff behavior. Its value is influenced by basin area, slope steepness, and rock type, with larger areas and steeper slopes generally resulting in longer, more defined circumferences. (Mohamed, 2023)

For the Targhath Wadi, the circumference reaches approximately 127 km, which is relatively small. This is attributed to the basin's small area and the tendency of watercourses to deepen their channels, especially in the mountainous sections of the basin. This topographic pattern affects the delineation of basin boundaries and its circumference, as channel deepening reduces the basin's lateral extent and concentrates flow toward the main channel. Therefore, valley circumference is an important indicator for characterizing the basin's topographic structure, understanding the nature of its boundaries and width, which in turn informs interpretations of surface runoff patterns and the management of associated water resources.

2. Morphometric Characteristics of the Targhath Valley Basin>

The applied morphometric study of basin shape is useful for measuring rates of water erosion, as it allows for determining the volume of water flowing through the main channel of the valley and its impact on landforms and basin areas. River basins take different geometric shapes, including circular, elongated, and triangular forms. Studying the morphometric characteristics of valley basins is also beneficial for identifying the stages of their development and the factors that shaped the valley, in addition to examining the relative relationships between the length and width of the valley based on its main characteristics, such as area, length, width, and perimeter. (Al-Barky, 2023)

Table (2): Morphometric Characteristics of the Targhath Valley Basin

Elongation Ratio	Circularity Ratio	Compaction Coefficient	Basin Shape Factor	Length-to-Width Ratio
0.3	0.20	2.05	1.20	2.57

Source: Prepared by the researcher through the morphometric analysis of the Targhat Valley.

A. Elongation Rate (EF). is a morphometric parameter used to describe basin shape and its deviation from circularity, ranging from 0 to 1. Values near 1 indicate a nearly circular basin, while values near 0 reflect an elongated form. EF is influenced by geological structures, slope characteristics, tectonic activity, climatic conditions, and processes of weathering and erosion. It is a valuable tool for comparing basins or sub-basins, helping to evaluate hydrological behavior, assess flood risk, and guide water resource management planning (Blair & Biss, 1967). The elongation rate is defined as the ratio between the diameter of a circle having the same area as the basin and the basin's maximum length, and it is expressed by the following formula: $EF = 2\frac{\sqrt{A/\pi}}{L}$

A = Basin area in square kilometers L = Maximum basin length in kilometers
π = Constant value (3.1416)

source (Blair and Biss, 1967)

The elongation rate of the Targhath Valley basin reached **0.3**, which is a low value indicating that the basin shape is far from circular and tends toward an elongated or stretched form. Values close to **1** represent basins with a circular shape, while lower values (less than 0.5) indicate long and extended basins. Accordingly, the value **0.3** clearly shows that the Targhath Valley basin has an elongated rather than a circular shape. This morphometric form results in several hydrological and geomorphological characteristics, the most notable of which are:

- **Longer time of concentration:** The elongated shape increases the distance that surface runoff must travel to reach the main outlet, which results in a longer concentration time and delayed peak discharge.
- **Lower likelihood of flash floods:** Unlike circular basins, which tend to collect water quickly and produce a high peak discharge, elongated basins are generally less prone to sudden flooding due to spatial and temporal dispersion of runoff.
- **More uniform discharge:** As stream channels are distributed over a wider area and flow paths are longer, discharge becomes more gradual, and water quantities may be spread over a longer period.
- **Expression of structural and tectonic influences:** An elongated basin shape is often associated with structural controls or lithological variations that influence

flow directions and the development of the drainage network, contributing to shaping the basin longitudinally.

- **Variable relief and slope:** The elongated shape may reflect greater diversity in topography, though this depends on additional factors such as rock structure and erosion processes. (Mohamed, 2023)
  A low elongation rate does not necessarily imply weak slopes or irregular watershed divides; rather, it may indicate the dominance of specific flow directions imposed by the geological structure. (Horton, 1932)

B. Circularity Ratio (CF). is the ratio between the basin area and the area of a circle whose circumference is equal to the basin perimeter. The circularity ratio indicates the degree of similarity between the basin shape and a perfect circle. Morphologically, the circularity ratio is considered the inverse of the elongation ratio, as it expresses how closely the drainage basin resembles a circular form (Mohamed, 2023). It is calculated as follows:

$$CF = \frac{4\pi A}{P2}$$

Where: CF = Circularity ratio of the basin P = Perimeter of the basin (km) A = Area of the basin (km²) π = Constant (3.1416)

(Horton, 1932)

The circularity ratio of the Targhath Valley basin reached **0.20**, which is a very low value and clearly indicates that the basin is elongated rather than circular. This is often attributed to structural or tectonic influences that control flow directions and the development of the drainage network, in addition to the role of lithological and erosional factors. The value of **0.20** indicates that the basin is far from circular and tends toward an elongated form, meaning that flow paths are extended and take longer to reach the basin outlet. The elongated shape can be interpreted as an adaptation of the drainage network to prevailing structural or lithological conditions. However, describing it as a direct indicator of the "development of the underlying cycle" requires further scrutiny, since the underlying cycle is more closely related to surface structure and erosion gradients than to basin shape alone.

Therefore, it can be said that a low circularity ratio may indicate the dominance of structural or tectonic factors in the basin's development, reflecting advanced stages of geomorphological adaptation. Circular basins are usually associated with a higher risk of flash floods due to rapid accumulation of runoff at the outlet. In contrast, elongated basins tend to reduce the likelihood of sudden floods because runoff is dispersed over a larger area and concentration time is delayed. Thus, the claim that a low circularity ratio "increases flood hazard" does not align with common hydrological interpretations. The correct understanding is that a low circularity ratio may reduce the likelihood of sudden peak discharge compared to circular basins.(Mohamed, 2023).

C. Compactness Coefficient (LF). measures the regularity of a basin's boundaries and its deviation from a circular shape. Values near 1 indicate a nearly circular, regular basin, while higher values reflect greater elongation or irregularity, showing a more complex basin shape. This coefficient helps assess how efficiently a basin directs water toward its outlet (Salama, 1982). It is calculated by dividing the square of the basin length by four times the basin area, according to the following morphometric equation: (Horton, 1932)

$LF = \frac{L2}{4A}$ Where: LF = Compactness coefficient of the basin L = Maximum basin length (km) A = Basin area (km²)

The compactness coefficient relates basin length to four times its area, reflecting how closely the basin resembles a pear-shaped form rather than a perfect circle. High values indicate an elongated basin with dominant vertical erosion, while low values suggest a more expanded shape with longer and more numerous lower-order channels shaped by both vertical and lateral erosion.

The Targhath Valley basin has a compactness coefficient of 1.20, indicating an elongated or rectangular shape rather than circular. This elongation results in longer flow paths, increasing time of concentration and reducing the likelihood of rapid flood peaks. While the coefficient reflects boundary regularity rather than erosion type, the elongation may suggest structural or tectonic influences on longitudinal flow, potentially enhancing vertical erosion along the main channel, though confirmation requires additional morphometric indicators.

D. Basin Shape Factor (BSF). The basin shape factor is used to determine the relationship between the dimensions of a drainage basin and its geometric form, with the aim of understanding surface runoff dynamics and estimating the hydrological behavior of basins. This indicator helps clarify the degree of elongation of the basin or its closeness to a circular shape, which affects the runoff rate and the time it takes for water to reach the basin outlet. It is expressed by dividing the basin area (km²) by the square of the basin length (km) (Awad Mohamed, 2015, p. 9). The basin shape factor of the Targhath Valley basin reached 0.20, a relatively low value, clearly indicating that the basin is more elongated than circular. Low values of the basin shape factor are generally associated with an increase in the relative length of the basin compared to its width. This value reflects several morphometric and hydrological implications, the most notable of which are:

- The elongated shape of the basin indicates that flow paths within the drainage network are relatively long before reaching the basin outlet, resulting in delayed water arrival and more dispersed runoff over time.
- Elongation increases the time required for runoff to concentrate at the main outlet, which limits rapid water accumulation and reduces the likelihood of a sharp peak discharge in a short period.
- Rectangular or elongated basins are usually less prone to flash floods compared to circular basins because runoff is distributed over a long and gradual network, making the basin’s response to rainfall more temporally distributed.
- The basin’s tendency toward elongation may also indicate structural or lithological influences that guide flow paths, such as faults or folds controlling drainage directions, leading to the development of a longitudinal basin form.

The basin shape factor value of **0.20** reflects a clear trend toward elongation in the Targhath Valley basin, which contributes to slower runoff concentration and delayed peak discharge, thereby reducing the likelihood of sudden flooding. This pattern also indicates morphologic and structural influences that have shaped the current form of the basin.

E. Length-to-Width Ratio. is one of the fundamental morphometric indicators used to describe the geometric shape of drainage basins and to measure their degree of elongation or closeness to a circular form. This indicator is both simple and precise, helping to understand surface runoff dynamics within the basin and interpret its hydrological behavior. It is calculated by dividing the basin length (km) by the basin width (km) (Awad Mohamed, 2015, p. 10). The morphometric analysis of the Targhath Valley basin showed that the length-to-width ratio reached **2.57**, a relatively high value that clearly indicates the basin tends to be elongated. Higher values of the length-to-width ratio indicate greater longitudinal extension of the basin relative to its width. This means that the maximum basin length is approximately 2.57 times its width. In simpler terms, roughly every 3 kilometers of length corresponds to about 1 kilometer of width, confirming the elongated nature of the basin.

The high value of the length-to-width ratio indicates that the Targhath Valley basin has an extended longitudinal shape, reflecting the long flow paths from the headwaters to the main outlet. The elongated form of the basin contributes to a longer time of surface runoff concentration, as precipitation takes more time to reach the outlet. This generally results in a more gradual response of the basin to rainfall events and reduces the likelihood of a sharp peak discharge over a short period. Elongated basins are generally associated with a lower probability of flash floods compared to more compact basins (circular or oval) because runoff is dispersed along long paths before reaching the outlet. The elongated shape may also reflect structural or tectonic influences that guided the drainage network along certain directions, and geological structures or variations in rock types may control the development of the basin's current form.

3. Topographic Characteristics of the Targhath Valley Basin.

Dry valleys are among the most prominent geomorphological features in arid and semi-arid regions, representing a direct result of the interaction between geomorphological processes and prevailing climatic conditions. These valleys have formed in environments characterized by scarce and irregular rainfall, leading to weak permanent flow that is often limited to seasonal floods, or in some cases, the absence of surface flow altogether. Dry valleys serve as a geomorphological record reflecting the stages of land surface development in arid environments and the influence of structural and lithological factors. Table (3) presents the main topographic characteristics of the Targhath Valley basin.

Table (3): Topographic Characteristics of the Targhath Valley Basin

Basin Topography	Relief Ratio	Relative Terrain	Ruggedness Value	Dissection Ratio	Hypsometric Integral
500m	13.5	335%	6.03	5.11	0.8

Source: Prepared by the researcher through the morphometric analysis of the Targhat Valley.

A. Basin Topography. Basin topography is a key morphometric indicator, reflecting the vertical difference between the highest and lowest points, which influences geomorphological and hydrological processes. In the Wadi Targhath basin, the highest elevation reaches about 501 meters above sea level, while the outlet is around 1 meter, resulting in a topographic difference of approximately 500 meters. This significant variation provides high topographic energy, promoting vertical erosion in headwater and steep-slope areas, and creating diverse landforms from rugged highlands to low-lying zones near the outlet where sediment deposition is common. Hydrologically, this gradient causes variable water responses: the upper basin experiences rapid surface runoff, while the lower basin responds more slowly, allowing greater sediment accumulation. Thus, the 500-meter topographic difference is a crucial factor in understanding runoff dynamics and the distribution of geomorphological processes within the Wadi Targhath basin..

B. Relief Ratio: The Relief Ratio is a key hydrological and geographical measure that relates a basin's elevation difference to its length, reflecting slope steepness and surface relief. High values indicate steep terrain, promoting faster water flow, increased erosion, and sediment transport, while low values suggest flatter areas with slower runoff, higher sediment deposition, and potential flooding. This ratio is crucial for assessing flood risk, guiding water resource projects like dams and channels, and informing land-use planning for agriculture and settlements (Salama, 1982). It is expressed by the following formula:

$$\text{Relief Ratio} = \frac{\text{Elevation difference between highest and lowest points in the basin}}{\text{Maximum length of the basin}}$$

(Cooke & Doornkamp, 1974)

Data indicate that the relief ratio of the Wadi Targhath basin is 13.5%**,** meaning that the land surface rises at an average rate of 13.5 meters per kilometer from the source to the mouth of the wadi. This ratio is high compared to river basins with moderate relief, reflecting the basin's steep slope and rugged surface. A high relief ratio indicates that the basin has a pronounced gradient, which increases water runoff speed through the channels and enhances the river's erosive capacity. This, in turn, suggests that Wadi Targhath is still in the early stages of its erosion cycle, dominated by vertical incision and active rock cutting rather than horizontal sediment deposition. Practically, these characteristics imply that the basin is susceptible to rapid runoff and higher flood risks during heavy rainfall. The steep relief also necessitates careful engineering and environmental considerations in land-use planning or infrastructure projects such as dams and channels to prevent excessive erosion or mudslides.

C. Relative Terrain. Relative terrain measures elevation differences within an area or river basin, reflecting slope steepness and land diversity. In the Wadi Targhath basin, a relative terrain value of 335% indicates significant topographic variation and steep slopes, characteristic of a youthful landscape dominated by vertical erosion rather than sediment deposition. This steepness enhances the capacity of watercourses to transport sediments, shapes channel development, and increases susceptibility to rapid surface runoff and flash floods. High relative terrain is therefore a crucial factor for understanding geomorphological dynamics and must be considered in land-use planning and infrastructure development within the basin (Mustafa, 1998). The relative terrain value of 335% shows that the Wadi Targhath basin possesses active geomorphological features and pronounced slopes, placing it among youthful basins in terms of the erosion cycle and requiring careful study of runoff and erosion processes for environmental and engineering assessments.

D. Ruggedness Value: The Ruggedness value is a key geomorphological measure that characterizes a basin's topography by combining elevation variability and drainage network density. It is used to assess how a basin responds to erosion and surface runoff and is calculated by multiplying drainage density by the elevation difference, then dividing by the basin perimeter.

In the Wadi Targhath basin, the Ruggedness Number (RN) is 6.03, indicating moderate to relatively high topographic complexity and a well-developed drainage network (Al-Dulaimi, 2001). This value reflects the combined effects of basin relief and drainage density, highlighting pronounced slopes and efficient watercourses capable of active erosion and sediment transport. The RN confirms that the basin is in an active geomorphological stage dominated by vertical incision. It is a crucial factor for land-use planning and engineering projects due to increased risks of surface erosion and sediment yield during floods. Moreover, the RN helps understand the spatial distribution of slopes and erosional features, providing essential insight for managing the basin's geomorphology and environmental resources effectively.

E. Texture Ratio (Dissection Ratio): The Texture Ratio measures the density of a basin's drainage network and the degree of surface dissection by watercourses. Basins are classified as coarse-textured (<4), medium-textured (4–10), or fine-textured (>10) (Awad Mohammed, 2015, p.12). In the Wadi Targhath basin, the texture ratio is approximately 5.11 channels per km², indicating a medium level of dissection. This reflects a moderately developed drainage network with an average concentration of watercourses, active but not extreme erosion, and moderate capacity for sediment transport. The medium texture suggests relatively regular fluvial processes influenced by geology, lithology, and climate, balancing erosion and deposition. The texture ratio thus provides key insight into the basin's geomorphological dynamics and hydrological response.

F. Hypsometric Integral: The Hypsometric Integral (HI) is a key parameter reflecting a basin's stage in its geomorphic cycle. Values range from 0 to 100, with higher values indicating youthful basins with high drainage density and lower relief (Issam Al-Burki, 2023, p.574). In the Wadi Targhath basin, the HI is approximately 0.5, indicating an intermediate stage of geomorphological development. This suggests the basin is still in an early erosion phase, dominated by vertical and lateral incision, with limited deposition. Medium HI values also imply a relatively small basin area and active topography, maintaining significant capacity for surface runoff, erosion, and sediment transport (Abu Al-Anein, 1995). Therefore, the HI confirms that Wadi Targhath remains in an initial stage of fluvial erosion, with ongoing geomorphological processes shaping its drainage network and overall topography.

4. Drainage Network Characteristics.

Analyzing the drainage network is essential for determining the developmental stage of river basins and understanding the relationship between lithology and climatic conditions**.** This is achieved by examining stream orders, number of channels, bifurcation ratio, drainage density, stream frequency, channel sinuosity, and drainage patterns, as outlined below:

A. Stream Orders: The stream ordering of watercourses within a basin constitutes one of the primary morphometric analyses of a river drainage network (Figure 4). Several methods exist for stream ordering, and the Strahler (1952) method was adopted for the

Wadi Targhath basin due to its simplicity and widespread use. According to this method, streams are ordered from the uppermost part of the basin (headwaters): headwater tributaries with no other tributaries entering them form first-order streams. When two first-order streams converge, they form a second-order stream; when two second-order streams join, a third-order stream is formed, and so on (Ahmed Mustafa, 1986, p.180). The study of stream orders in Wadi Targhath revealed the presence of five stream orders, with a total of 353 channels in the basin, as shown in Table (4).

B. Bifurcation Ratio: The bifurcation ratio is defined as the ratio between the number of streams of a given order and the number of streams of the next higher order. Table (4) presents the bifurcation ratios for Wadi Targhath. Variations in bifurcation ratios within the wadi can be attributed to probabilistic factors or chance in the development of any river drainage network. Typically, basins with uniform lithology and similar climatic conditions exhibit very consistent bifurcation ratios (Ahmed Mustafa, 1986, p.180).

Table (4): Stream Orders, Number of Streams, and Bifurcation Ratios

Order	Number of Streams	Bifurcation Ratio
1	178	—
2	91	1.9
3	32	2.8
4	16	2
5	36	0.4

Source: Prepared by the researcher based on the morphometric analysis of Wadi Targhath.

C. Stream Lengths: This involves measuring the lengths of watercourses using Geographic Information Systems (GIS) technology. The stream lengths were as follows:

Table (5): Total Stream Lengths (km) of Wadi Targhath

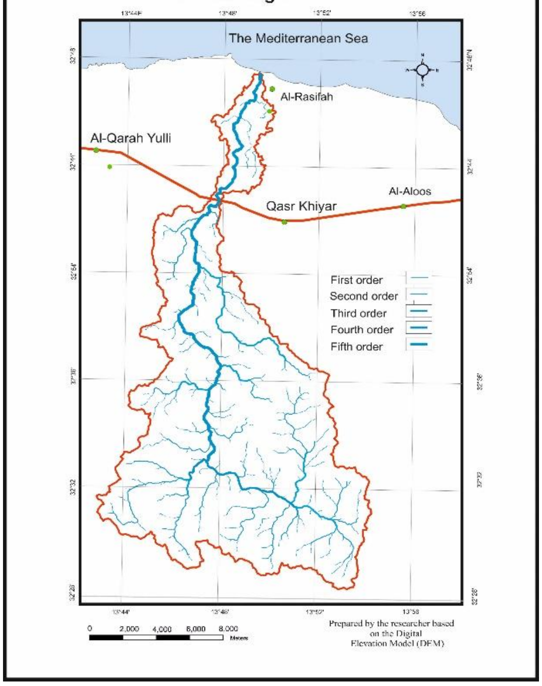
Order	Number of Streams	Total Stream Length (km)
1	178	147
2	91	84
3	32	27
4	16	10
5	36	34

Source: Prepared by the researcher based on the morphometric analysis of Wadi Targhath.

D. Stream Frequency: Stream frequency is one of the fundamental morphometric indicators used to analyze the characteristics of drainage basins. It is defined as the number of streams per unit area of the basin. This indicator reflects the degree of development and dissection of the drainage network. High values occur in basins with dense stream networks, indicating geomorphological conditions favorable for the formation of river channels, such as increased rainfall, steep slopes, erodible and varied lithology, and sparse vegetation cover. Conversely, low stream frequency indicates limited development of the drainage network, often due to low rainfall, predominance of impermeable hard rocks, or dense vegetation cover that inhibits stream formation. Accordingly, stream frequency is an important indicator for assessing the hydrological structure of a basin and its responsiveness to precipitation, as well as for interpreting geomorphological patterns and surface processes. Stream frequency is calculated by dividing the total number of streams of all orders in the basin by the basin area (Ahmed Mustafa, 1986, p.183).

The analysis results indicate that the stream frequency in the Wadi Targhath basin is approximately 1.32 streams/km², a value considered moderate to relatively high compared to some neighboring basins in the Al-Jifarah region. This result suggests that the basin possesses a relatively well-developed drainage network, reflecting a high capacity of fluvial erosion processes to shape channels and maintain their effectiveness within the basin's hydrological system. The elevated stream frequency indicates a clear density of channels relative to the basin area, which can be attributed to several geomorphological and climatic factors. Chief among these are the erodibility of the basin's lithology, which promotes the formation of secondary and tributary channels, and the relative slopes of the terrain, which facilitate rapid water flow and the creation of new channels, along with variability in rainfall amounts that influence the development and continuity of the drainage network. This value also suggests a rapid hydrological response of the basin to precipitation, indicating relatively efficient surface runoff with likely low infiltration and percolation rates. Accordingly, a stream frequency of 1.32 streams/km² serves as an indicator of a morphologically and hydrologically active basin, characterized by medium to high surface water drainage efficiency, which directly impacts the dynamics of surface processes and the development of landforms in the region.

Figure(3) The stream orders of Wadi Targhat Basin



F. Drainage Intensity, defined as the total length of streams per unit area, is a key hydromorphometric indicator reflecting the development of a basin's drainage network and its relationship with geomorphology, hydrology, and geology (Horton, 1932). High values occur in steep, impermeable, sparsely vegetated, or high-rainfall basins, while low values correspond to gentle slopes, permeable soils, dense vegetation, or arid climates. Factors influencing drainage density include geology, slope, climate, soil type, vegetation, and overall basin morphology. In the Wadi Targhath basin, drainage density is 1.3 km/km², indicating a moderate value that balances surface runoff with soil and rock permeability. This suggests moderate to gentle slopes, partial vegetation influence, and semi-arid to semi-humid climate conditions, with a relatively efficient drainage network capable of moderate surface water discharge. The basin allows partial groundwater infiltration and has reduced flash flood risk compared to basins with higher drainage densities.

E. Calculating the Slope Intensity of Wadi Targhath Basin.

Slope analysis is one of the fundamental indicators in morphometric studies of drainage basins due to its importance in determining the nature of the topographic surface, the behavior of surface runoff, and erosion and deposition processes. The following table illustrates the slope gradient of Wadi Targhath Basin across six main classes ranging from 0° to 44°:

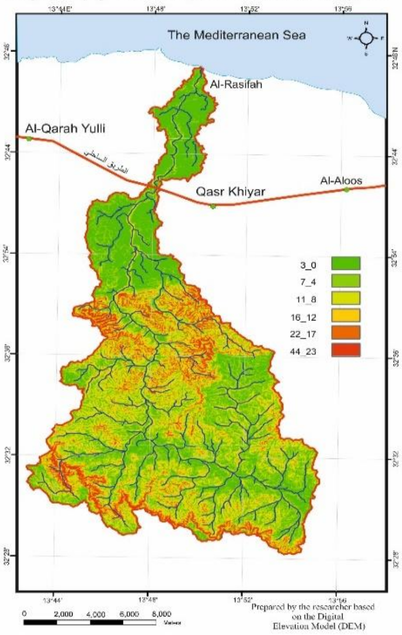
Table (6): Slope Degree of Wadi Targhath

Slope Class (Degrees)	General Description of Slope
0 – 3	Very gentle slope
4 – 7	Gentle slope
8 – 11	Moderate slope
12 – 16	Moderately steep
17 – 22	Steep slope
23 – 44	Very steep slope

Source: Derived from the digital elevation model (DEM) analysis of the study area.

The Wadi Targhath Basin exhibits a clear slope gradient, ranging from gentle slopes (0–7°) in the lower plains, where deposition dominates and agricultural soils form, to moderate slopes (8–16°) in transitional zones, and steep to very steep slopes (17–44°) in the upper mountainous areas, where erosion and sediment transport intensify. This diversity in slope reflects a complex topography influencing drainage behavior: low-slope areas accumulate water and sediments, while high-slope zones enhance surface runoff and recharge. Overall, the basin shows a moderate slope gradient from upper elevations to flat plains near the outlet, creating a balanced morphometric and hydrological system. This semi-stable configuration reduces flash flood risk, supports groundwater recharge, and allows a controlled distribution of hydrological energy across the basin.

Figure (4) The Slopes in Wadi Targhat



Results:

1. The combined morphometric parameters indicate that Wadi Targhath is in the youthful stage of the erosion cycle, where vertical erosion processes dominate, steep slopes prevail, and the drainage network is gradually developing. This reflects that the fluvial system is still undergoing geomorphological formation and has not yet reached a stage of equilibrium or dominant deposition.
2. The study of the areal characteristics of Wadi Targhat shows that the basin is relatively small compared to other wadis, with an area of **242 km²**. This limited size is reflected in the drainage density: the basin length of **41 km** is relatively short, resulting in accelerated surface runoff and reduced infiltration rates within the basin.
3. The analyses indicate that the basin shape tends toward a rectangular form, suggesting that the wadi is still in an early phase of the erosion cycle, where headward erosion dominates along the wadi's main course.
4. The relief ratio, which reached **12.4**, reflects that the wadi is in the youthful stage of geomorphological development, due to the intensity of fluvial erosion processes typical of this stage.
5. The high slope values demonstrate the steep gradient of the wadi, which enhances the dominance of fluvial erosion. The ruggedness value of **6.03** further highlights this steepness.
6. The study revealed a low drainage density of **1.8**, attributed to the limited area of the upper catchment compared to the total basin area, which reduces the volume of water feeding the main wadi channel.

Recommendations:

1. It is recommended to construct check dams to control the velocity of surface runoff and enhance the recharge of the groundwater aquifer fed by the wadi.
2. Morphometric and geomorphological studies of the wadi should continue to better understand its behavior, contributing to the optimal economic use of water and basin resources.
3. Specialized economic studies are recommended to assess the feasibility of constructing dams on the wadi, in order to ensure efficient and sustainable utilization of the available water resources.
4. Rain-fed agriculture should be encouraged within the basin, particularly the cultivation of olive and almond trees, due to the suitability of the climate and soil for these crops.
5. Attention must be paid to potential flood risks in the wadi, especially under extreme climatic conditions, to avoid disasters similar to the Derna incident.
6. The results of this study should be utilized to improve the management of agricultural lands within the basin, incorporating watershed management principles and water-harvesting techniques to achieve optimal use of available water resources.

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