

Analysis of the Morphometric Characteristics and Their Relationship with the River Network Properties of Valley Al-Amghar Basin, Southwestern Al-Muthanna Desert: An Applied Statistical Study

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Abstract

Valley Al-Amghar basin, located in the southwestern part of the Al-Muthanna desert, is characterized by its flat terrain and general topographic smoothness with minimal relief variations. The basin extends over a length of 85.32 km with a low topographic difference of 158 meters, resulting in a gentle slope averaging 1.85. This has significantly influenced sedimentary properties and the flow velocity within the basin. The basin contains 7,747 watercourses, reflecting the impact of topographic factors on the fluvial network's characteristics and including stream orders, lengths, and both numerical and linear drainage densities. The study focuses on the influence of low-gradient terrain on the development of the fluvial network, employing geomorphological indicators such as relative relief, ruggedness ratio, and hypsometric integral. Stream orders are classified using Strahler's method. Results indicate that larger sub-basins exhibit a greater number and length of streams, with a positive correlation between basin area and stream number, and an inverse relationship between hypsometric integral and topography. Stream density increases in areas with moderate slopes and softer lithology, while the hypsometric integral decreases as ruggedness increases.

Keywords:

Al-Amghar, Ruggedness Ratio, River Network, River Orders, Pearson.

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1. Introduction

The study of the relationship between terrain characteristics and river network properties is a vital topic in morphometric studies and water resource management (Schumm and Sugden, 1984). Such studies contribute to understanding the behavior of river basins and their capacity to manage floods and optimize water resource utilization (Strahler, 1952). This research aims to analyze the relationship between the topography of the Al-Amghar Valley basin and the properties of its river network, emphasizing how topographic features influence surface runoff dynamics and the basin's ability to form efficient river networks (Horton, 1945). Topography plays

a pivotal role in defining river network characteristics, including stream orders, channel lengths, and both numerical and linear densities. Variations in slopes highlight differences in relief, which are determined by rock types influencing surface runoff dynamics and water velocity within the basin. These variations significantly impact the sedimentary processes and erosion patterns (Summerfield, 2014 and 1991; Tarboton, 1997; Bishop, 2004). Topographic features also shape the river networks by influencing water distribution and flow. Areas with gentle slopes often exhibit higher network density due to slower runoff (Qin and Wang, 2022; Boothroyd, 2023; Rahaman et al., 2017). Analyzing this relationship aids in understanding the geomorphological processes and environmental planning by

revealing how topography shapes local hydrology, streamflow patterns, and water discharge (Arefin and Alam, 2020; Gajbhiye, 2014).

2. Materials and Methods

Study Area

The Valley Al-Amghar basin is located in the southwestern Badia of Al-Muthanna Governorate in Iraq. Geographically, the basin lies between latitudes 29°42'21"N and 28°56'37"N, and longitudes 45°09'60"E and 45°43'50"E. The basin spans an area of 1778.76 km², with 1504.55 km² (84.5% of its area) situated within the administrative boundaries of Al-Muthanna Governorate, while the remaining 274.21 km² (15.5%) extends into the Kingdom of Saudi Arabia (Fig. 1) (Jasib, 2011; Ministry of Water Resources, 2013; Directorate of Al-Muthanna Municipality, 2022).

A. Geology

The basin falls within the Salman Zone, which is part of a secondary fault network including the Euphrates Fault, stretching from the northeast to the southeast (Wajid, 2017). This zone is characterized by geological formations from the Tertiary and Quaternary periods (Al-Zurfi, 2021), as given in Table (1).

Table 1: Geological formations in the Al-Amghar basin.

Geological time	Geological Formation	Area (km ²)	Percentage (%)
Tertiary Deposits	Dibdibba Formation	1236.31	69.5
	Middle Dammam Formation	356.54	20.04
	Upper Dammam Formation	103.11	5.8
	Al-Zahra Formation	3.49	0.2
Quaternary Deposits	Depression-Fill Deposits	52.84	2.97
	Valley-filling Deposits	26.47	1.49
Total		1778.76	100

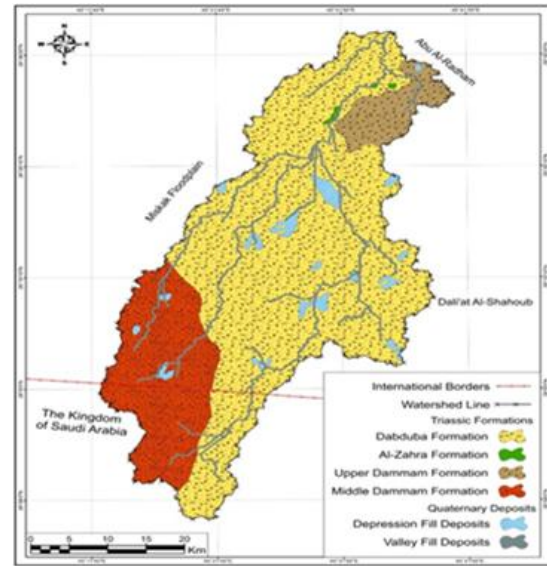


Fig. 1: Location and geology of valley Al-Amghar in Iraq.

B. Climate of the Al-Amghar basin

The climate of the Al-Amghar basin is characterized by long dry periods throughout the year. It is influenced by a variety of climatic variables, with temperature and precipitation being the most significant. Data from six surrounding meteorological stations (Basra, Nasiriyah, Samawah, Hafar Al-Batin, Rafha, and Al-Qaisumah) provide insights into these climatic conditions (Table 2).

The region experiences high temperatures in the summer ranging from 34.6°C to 39.1°C. In winter, the temperature drops to a range between 12.7°C and 14.2°C. The annual average temperature fluctuates between 24.4°C and 27°C.

Precipitation is almost nonexistent during the summer months. In winter, however, rainfall ranges from 45.9 mm to 79.4 mm with the total annual rainfall varying between 99 mm and 127.3 mm depending on the station.

Table 2: Climatic data (temperature and precipitation) of the study area (2000–2023).

Seasons			Stations					
			Samawah	Nasiriyah	Basrah	Rafha	Hafar Al-Batin	Qaisumah
Winter	Temperature	Average	13.9	14.2	14.2	12.7	13.6	14.2
	Rainfall	Total	46.2	55.8	79.4	45.9	54	58
Spring	Temperature	Average	26.6	26.3	26	24.2	25.9	26.5
	Rainfall	Total	32	32.1	22.3	30.1	29	30
Summer	Temperature	Average	38.3	39.1	38.4	34.6	35.9	36.9
	Rainfall	Total	0	0	0	0	0	0
Autumn	Temperature	Average	27.5	28.3	27.9	25.8	26.6	27.6
	Rainfall	Total	34.8	28.4	25.6	23	29	28
Annual Average		Temperature	26.6	27	26.6	24.4	25.6	26.3
Annual Total		Rainfall	113	116.3	127.3	99	112	116

3. Results Topographic Characteristics

The topographic features of the Al-Amghar basin represent the final form of the watershed, shaped by geomorphological factors such as weathering and erosion. Weathering processes break down rocks into smaller pieces, which are then transported by erosional forces (water and wind). These processes contribute to the change in the basin's topography, influenced by geological formations since the basin's inception to the present day (Maria and Lestiana, 2018). Topographic characteristics vary among different basins and attributed to many factors such as rock type, vegetation, soil, and climate. The topography tends to be more rugged in areas with geological weaknesses, especially during successive geological periods (Shekar and Mathew, 2023). To understand these features, it is essential to analyze the spatial characteristics of the basin (Table 3). The basin's size can impact water runoff and river network density, thereby influencing the development of topographic features. The basin's spatial dimensions, particularly its longitudinal dimensions, are key to understanding these features.

Table 3: Spatial Characteristics of the Al-Amghar and its sub-basins.

Basin	Area (km ²)	Percentage %	Basin Length (km)	Basin Width (km)
1	736.47	41.41	73.13	10.0
2	866.32	48.70	65.8	13.1
3	78.24	4.39	13.84	5.65
4	97.73	5.50	23.73	4.11
Average	444.69	25	44.12	8.21
Al-Amghar	1778.76	100	85.32	20.84

A. Relief Ratio

The slope steepness ratio is a measure of the average gradient of the basin and represents the topographic relief affecting water flow and

sediment transport. This ratio helps in determining the density, frequency, and depth of the river network as well as the amount of sediment carried by the flow (Petticrew and Lobb, 2013). It is calculated using the following formula (Strahler, 1957).

$$\text{Ruggedness Ratio} = \frac{\text{Difference between the highest and lowest points in the basin (m)}}{\text{Basin length (km)}}$$

From Table (4), it is clear that the ruggedness ratio in the basin reached 1.85, and the average of the secondary basins is 2.75. There is variation in the relative ruggedness between the secondary basins with the third basin recording

the highest value of 3.68, while the second basin recorded the lowest value of 1.62. It is evident from the table that the third and fourth basins recorded the highest values of 3.68 and 3.66 respectively. This is due to the smaller size of these two basins compared to the others and the proximity of the contour lines, which leads to increased river erosion. On the other hand, the first and second basins recorded values of 2.05 and 1.62 respectively. This decrease is attributed to the larger size of these two basins and the wider spacing of the contour lines indicating lower slopes, which leads to a lower ruggedness ratio. The variation between the secondary basins is not large indicating similar environmental conditions and the dominance of low-resistant rocks to water and wind erosion processes. Overall, all the ruggedness ratio values are considered low compared to basins located in mountainous areas, where this ratio can exceed 100.

B. Relative Relief

Relative relief illustrates the relationship between the topographic range and the perimeter of the basin, representing the degree of ruggedness of the drainage basins. High values

indicate the inability of the rocks to resist erosion and their geological weakness, while low values indicate the high resistance of the rocks. It is calculated according to the following relationship (Melton, 1957).

$$= (\text{Basin Relief}) / (\text{Basin Perimeter in km}) * 10 \\ \text{Relative Relief}$$

Table (4) reveals that the mean relative relief of the Al-Amghar watershed is 5.39, while the mean of the sub-watersheds is 8.77. There is a significant variation among the sub-watersheds, with the fourth sub-watershed recording the highest value of 13.46, attributed to its small size and closely spaced contour lines. Conversely, the second sub-watershed recorded the lowest value of 4.81 due to its larger size, being the largest among the sub-watersheds. The higher values of relative relief result in increased surface runoff velocity and affect the characteristics of river flow consequently.

C. Ruggedness Value

It is a measure used to determine the extent of the impact of topography on the river network and the intensity of drainage within the basin. It illustrates the relationship between the topographic development of the basin and the branching of river channels. Alternatively, it is the process of measuring the relationship between the ruggedness of the basin and the length of the river drainage network. Strahler (1964) confirmed that a higher value of this indicator indicates an increase in drainage density due to the increase in the number of channels. The decrease in this value is due to the lower number of channels and the smaller size of the basin. It is calculated according to the following equation (Minár and Evans, 2008).

$$\text{Ruggedness Value} = (\text{Basin Relief}) * (\text{Drainage} \\ \text{Density}) / 1000$$

From Table (4), it is also clear that the average ruggedness value in the study area is 0.27, and the average for the secondary basins is 1.37. There is a clear variation between the secondary basins, with the fourth basin recording the highest value of 2.68. This is due to the intensity of ruggedness and the presence of water erosion during rainfall, which transported sediments down the slopes from the upper reaches

of the basin. Water erosion alters the shape of the basin and increases the branching of the drainage networks, leading to higher ruggedness in this basin. On the other hand, the second basin recorded the lowest value of 0.38, which is attributed to the less intense topography and the gentler slope in this basin.

D. Hypsometric Integration

It is an index that shows the relationship between the basin area and its topography, and the results of this index indicate the geomorphological stage reached by the basin. It is expressed by the following equation (Strahler, 1952).

$$\text{Hypsometric Integration} = (\text{Basin Area in km}^2) / \\ (\text{Basin Relief in m})$$

From Table (4), it is clear that the average hypsometric integration for the study area is 11.25, and the average of the secondary basins is 3.91. As for the secondary basins, there is a clear variation, with the second basin recording the highest value of 8.09. This increase in value, along with the main basin, is due to the larger area of these basins, indicating an advanced stage in the erosion cycle, where the topography becomes more level. These basins are characterized by a flatter surface, unlike the fourth basin, which recorded the lowest value of 1.12. This is attributed to its smaller area and more rugged topography, indicating a less mature geomorphological stage with more prominent topographic features.

E. Geomorphic Number

It is a measure that shows the relationship between the topography (ruggedness) and the slope degree of the surface in the river basin. It depends on the drainage density and slope, reflecting the mutual influence between them in the formation of the basin's geomorphological surface. The geomorphic number is directly proportional to the slope, where a low geomorphic number indicates less sloping topography, while a high value indicates steep topography (Ahmed, 2016).

$$\text{Geomorphic Number} = \text{Ruggedness Value} / \\ \text{Ruggedness Ratio}$$

It can be observed from Table (4) that the average geomorphic number for the study area is 0.14, indicating the presence of moderately

sloping topography in the region. Meanwhile, the secondary basins recorded a higher average of 0.43, suggesting steeper topography compared to the main basin. The second basin recorded the lowest geomorphic number of 0.23, which is due to the larger area of this basin, leading to more

level topography. On the other hand, the fourth basin recorded the highest value of 1.11, indicating more rugged topography. Moreover, it is clear in Table (4) that the surface slope within the basin is relatively gentle due to the less varied topography

Table 4: Topographic characteristics of the secondary basins in the Al-Amghar basin.

Basin	Maximum Elevation in the Basin (m)	Minimum Elevation in the Basin (m)	Ruggedness Ratio (m/km)	Relative Relief	Ruggedness Value	Hypsometric Integral	Geometric Number
1	367	217	2.05	6.95	0.62	4.90	0.30
2	375	268	1.62	4.81	0.38	8.09	0.23
3	287	236	3.68	9.89	1.80	1.53	0.48
4	312	225	3.66	13.46	2.68	1.12	0.73
Average	335.25	236.5	2.75	8.77	1.37	3.91	0.43
Al-Amghar	375	217	1.85	5.39	0.27	11.25	0.14

Moreover, it is clear in Table (4) that the surface slope within the basin is relatively gentle due to the less varied topography between the basins, indicating a relative flattening of the terrain and a decrease in slope variation between the secondary basins.

4. Characteristics of Drainage Networks

Drainage networks are a true reflection of the natural conditions, including geological structure, climatic conditions, and tectonic factors. These factors, such as the type of rocks, tectonic uplift movements, rainfall, and the effect of temperature on weathering, determine the shape and design of drainage networks. Additionally, climate plays a crucial role in determining the density and temporal distribution of water, thus influencing the formation of drainage networks.

A. River Order

River order is defined as a classification system used to determine the rank of watercourses based on their connection to other streams. It starts from the streams that have no tributaries (first order) to the main rivers that receive flow from multiple tributaries (Miller and Wohl, 2020). The researcher relied on the Strahler (1952) method for calculating river orders, which is one of the simplest and most effective methods for determining river hierarchy (Fig. 2). Due to the simplicity of this method, it has been made easier to compare river basins with other studies. The variation in the number of river orders is due to the nature of the rocks that make up the basin. An increase in their number indicates that the rocks

are resistant to channel widening. Conversely, in less resistant rocks, the number of streams decreases, but their width increases (Charlton, 2007).

Table (5) shows that the total number of river orders in the Al-Amghar basin is 7,747 watercourses. The number of streams varied according to the level of each order, with the first-order streams totalling 5,869, which represents 75.75% of the total watercourses in the basin. The second order recorded 1,454 streams, accounting for 18.76%, while the third order had 329 streams, or 4.24%. The fourth order had 77 streams, representing 0.99%. The fifth, sixth, and seventh orders recorded 14, 3, and 1 stream, respectively, accounting for 0.18%, 0.05%, and 0.03%. It can be observed from Table 5 that the number of streams decreases as their order increases. (Table .5) also compares the river orders among the different basins. It shows that the second basin is recorded as the highest in river orders with 3,618 streams, or 46.70% of the total watercourses. This is due to the large area of this basin, which is the largest secondary basin in terms of area (866.32 km²), representing 48.70% of the total basin area. This larger area results in greater water flow and, consequently, more streams. In contrast, the third basin records the lowest number of river orders with only 356 streams, accounting for 4.59% of the total river orders in the basin. This is also due to its smaller area, as it has the smallest area among the secondary basins, with 78.24 km², or 4.39% of the total area, leading to less water yield and fewer streams.

Table 5: Orders of drainage networks and total number of channels for the Al-Amghar basin

Basin	First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order	Seventh Order	Total km	Percentage%
1	2519	638	145	30	6	2	1	3341	43,12
2	2743	677	151	40	6	1	0	3618	46,70
3	274	61	17	3	1	0	0	356	4,59
4	333	78	16	4	1	0	0	432	5,59
Al-Amghar	5869	1454	329	77	14	3	1	7747	100
Percentage%	75,75	18,76	4,24	0,99	0,18	0,05	0,03	100	-

B. Stream Lengths

The total length of the watercourses in the Al-Amghar basin is 5,509.1 km. The stream lengths vary between the different orders. The first order has the highest total length of 3,118.47 km, representing 56.60% of the total length of the basin. This increase in length is due to the higher number of first-order streams, which account for 5,869 streams, or 75.75% of the total number of streams in the study area. There is a direct correlation between the number of streams and their lengths in each order, where the total length increases with the number of streams, especially in lower river orders, which tend to have longer lengths due to higher stream density. The second order recorded a total length of 1,228.17 km, or 22.29%. The third order recorded 598 km, or 10.85%. The total length of the fourth order was 285.88 km, or 5.18%; the fifth order recorded 128.51 km, or 2.33%; the sixth order recorded 122.38 km, or 2.22%; and the seventh order recorded 28.16 km, or 0.53%. The variation in stream lengths is also attributed to geomorphological factors such as slope, rock permeability, and topographic conditions. Steep areas tend to have longer streambeds due to increased surface runoff and faster water flow. Regarding the secondary basins, it can be observed from Table (6) that the second basin recorded the highest stream length of 2,725.1 km, or 49.46%. This is due to the fact that this basin is the largest in area and has the highest number of watercourses. Therefore, it is natural for the stream lengths to increase with the number of streams due to the large size of the basin compared to other secondary basins. On the other hand, the third basin recorded the lowest total length of 217.19 km, or 3.96%, due to the same factors mentioned above. The third basin is the smallest in area among the secondary basins in the study area.

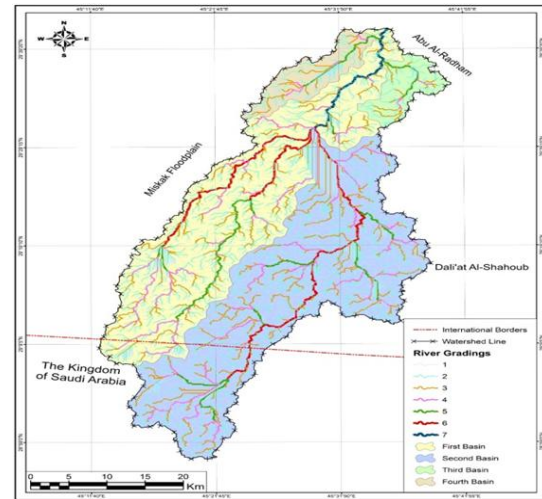


Fig. 2: River orders in the Al-Amghar basin.

C. Stream Length Rates

This function is derived by dividing the total length of watercourses in a given order by the number of streams in that order (Strahler, 1957) as follows:

Stream Length Rate for a given order = Total length of streams in that order / Number of streams in the same order

According to Table (7), the average length of the watercourses in the study area is found to be 0.71 km. Regarding river orders, the first order recorded the lowest average length, at 40.79 km. As for the secondary watersheds, the variation in watercourse lengths is minimal. The third watershed recorded the lowest average length at 0.61 km, due to the lower number and lengths of the watercourses in this watershed, which is smaller in area compared to the other secondary watersheds. In contrast, the second watershed recorded the highest average length, attributed to the increased number and length of watercourses due to the larger area of this watershed, which is the largest among the secondary watersheds in the study area.

Table 6: Total Lengths of River Orders in the Al-Amghar basin.

Basin	First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order	Seventh Order	Total km	Percentage%
1	1248.52	542.21	219	127.92	47.19	57.4	28.16	2270.54	41,21
2	1585.93	564.37	314	142.48	53.12	64.99	0	2725.1	49,46
3	119.58	51.24	28	6.24	11.95	0	0	217.19	3,96
4	164.45	70.36	36	9.24	16.25	0	0	296	5,37
Al-Amghar	3118.47	1228.17	598	285.88	128.51	122.38	28.16	5509.1	100
Percentage%	56,60	22,29	10,85	5,18	2,33	2,22	0,53	100	

Table 7: Average lengths of watercourses in the Al-Amghar basin.

Basin	First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order	Seventh Order	Total km
1	0,49	0,84	1,51	4,26	7,86	28,7	28,16	0,67
2	0,57	0,83	2,07	3,56	8,85	64,99	0	0,75
3	0,43	0,84	1,64	2,08	11,95	0	0	0,61
4	0,49	0,90	2,25	2,31	16,25	0	0	0,68
Al-Amghar	0,53	0,84	1,81	3,71	9,17	40,79	28,16	0,71

D. Drainage Density

Drainage density refers to the spread of the river network (streams and channels) and its tributaries within the area of the river basin. The spread of the network varies depending on the geological structure, soil type, vegetation cover, and slope. Drainage density indicates how fragmented the Earth's surface is by watercourses. Two types of drainage density can be distinguished:

Longitudinal Drainage Density: This refers to the ratio of the total length of the watercourses in the river basin to the total area of the basin. This relationship can be expressed mathematically by the following equation (Anderson and Anderson, 2010).

$$\text{Longitudinal Drainage Density} = \frac{\text{Total length of watercourses, km}}{\text{Area of the basin, km}^2}$$

This criterion is directly proportional to water discharge. As observed in Table (8), the longitudinal drainage density in the study area is 3.09 km. Regarding the secondary watersheds, the variation is very minimal. The second watershed recorded the highest value at 3.14 km, which is attributed to the larger area of this watershed, leading to an increase in the number of river channels. On the other hand, the third watershed recorded the lowest value at 2.77 km. This slight variation between the secondary watersheds may be due to the harmony and consistency in the geological formations that make up each watershed.

Numerical Drainage Density: It refers to the number of watercourses present within a unit

area of the river basin. This can be calculated using the following equation (Harrel and Dorris, 1968).

$$\text{Numerical Drainage Density} = \frac{\text{Total number of watercourses of all orders}}{\text{Area of the basin km}^2}$$

From Table (8), it is clear that the numerical drainage density in the study basin area is 4.35 channels/ km². As for the secondary watersheds, the variation between them is very minimal. The third watershed recorded the highest value at 4.55 channels/km², which is due to the smaller size of the watershed, as there is an inverse relationship between numerical density and area. On the other hand, the second watershed recorded the lowest value at 4.17 channels/km², due to its larger area. It is observed from Table (8) that there is an inverse relationship between numerical and longitudinal density. The values of longitudinal density increase with the increase in the area of the basin. Thus, the highest value is recorded in the second watershed at 3.14, which is the largest secondary watershed. The lowest value is recorded in the third watershed, which is the smallest in area among the secondary watersheds. Conversely, there is an inverse relationship with numerical density, where the values increase as the area decreases and decrease as the area increases, in contrast to longitudinal density, which decreases with larger areas and increases with smaller areas. This confirms the findings in Table 8.

Table 8: Longitudinal and numerical drainage density, and basin texture of valley Al-Amghar basins.

Basin	Drainage Density (Length)	Drainage Density (Numerical)	Topographic Texture	Actual Length (km)	Ideal Length (km)
1	3.08	4.53	15.49	73.13	71.16

2	3.14	4.17	16.28	65.8	63.09
3	2.77	4.55	6.90	13.84	12.90
4	3.02	4.42	6.68	23.73	22.6
Al-Amghar	3.09	4.35	26.43	85.32	83.12

E. Basin Texture

Basin texture is an indicator that measures the degree of convergence and divergence between watercourses within a basin. Basin texture is influenced by a set of natural factors, the most important of which are the type of rocks, topography, climate, soil, as well as natural vegetation, regional tectonics, and the geomorphological stage the basin is undergoing. It can be calculated using the following equation (Kauffman, 1977)

$$\text{Basin Texture} = \frac{\text{Number of Watersheds}}{\text{Perimeter of the Basin}}$$

From Table (8), it is evident that the average basin texture for the study area is 26.43, indicating a fine basin texture. Basins are classified into three categories based on the value of basin texture: Category 1: Coarse texture (0-4); Category 2: Medium texture (4-10); Category 3: Fine texture (greater than 10) (Scheidegger, 1966). The average value of the secondary watersheds is 10.21, with noticeable variation among the secondary basins. The first watershed recorded the highest value at 15.49, while the fourth watershed recorded the lowest value at 6.68, indicating medium roughness. The high value of basin texture in the valley is attributed to the large number of river tributaries that characterize the watershed.

F. Bifurcation Ratio

This ratio is defined as the number of channels in a given river order divided by the

number of channels in the next higher river order. Typically, the natural bifurcation ratio ranges between 3 and 5 undersimilar geological and climatic conditions within the basin. It is calculated using the following equation (Guha and McGregor, 2009).

Bifurcation Ratio = Number of channels in a given river order / Number of channels in the next higher river order

The bifurcation ratio is one of the most important morphometric variables that indicates the degree of water discharge and helps predict flood risks. Any increase in the bifurcation ratio signifies an increase in the process of water erosion caused by an increase in the amount of rainfall. As a result, the ability of water to transport sediment load increases. A higher bifurcation ratio through river channel systems contributes to the development of first-order channels into second-order channels, which -in turn- leads to the widening and deepening of watercourses and a retreat of the watershed divide (Kaufmann and Weber, 2011). Table (9) illustrates the bifurcation ratio in the study area, which is 4.31. Regarding the bifurcation ratio of the river orders, the fourth order recorded the highest value at 5.5, while the sixth order recorded the lowest value at 3. The remaining river orders varied between these two values. As for the secondary watersheds, the second watershed recorded the highest value at 4.32, while the first watershed recorded the lowest value at 3.86 (Table 9). All values in both the main basin and the secondary basins fall within the range of 3-5, which confirms the similarity of the geological and climatic conditions that constitute the basin.

Table 9: Bifurcation ratios in the Al-Amghar basin.

Basin	First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order	Bifurcation Ratio
1	3.94	4.4	4.83	5	3	2	3,86
2	4.05	4.48	3.77	6.66	6	1	4,32
3	4.49	3.58	5.66	3	-	-	4,18
4	4.26	4.87	4	4	-	-	4,28
Al-Amghar	4.03	4.41	4.27	5.5	4.66	3	4,31

G. Pearson's Statistical correlation importance

This correlation between terrain characteristics and river network properties is of great importance in hydrological studies. Terrain

directly influences the development of river networks through slope and gradient, which, in turn, determines how responsive the watersheds are to the development of river orders (Lane, 2002). This relationship helps in identifying the basin's ability to generate surface runoff within its

unique terrain environment. In this study, the researcher relied on statistical analysis using Pearson's correlation coefficient to measure the strength of the relationship between these variables and to determine their mutual effects. It is expected that the results will contribute to improving the understanding of surface runoff dynamics, thereby providing scientific applications in water resource management and flood prediction (Naghetini, 2017). The data for terrain characteristics and river network properties are obtained using the GIS 10.8 program relying on digital elevation models (DEM), in addition to field studies of the basin for accurate observation of these characteristics. Table (10) illustrates the correlation between terrain characteristics. It shows a strong positive relationship between the slope percentage and relative terrain, where watersheds with higher relative terrain tend to have a higher percentage of slope. This suggests that areas with steeper terrain may experience higher erosion rates, indicating a significant effect of slope on sediment transport and soil erosion processes. This also applies to the roughness value, which is a result of the relative terrain with a very strong positive correlation. The geometric number also follows this trend except for the hypsometric integral. Finally, the exception to this positive correlation is the hypsometric integral, which exhibits an inverse relationship with all terrain characteristics. This could be due to areas with higher hypsometric integral values being less prone to erosion, indicating that more stable, less steep terrains are less susceptible to surface erosion due to surface runoff (Strahler, 1964). As shown in the table, terrain characteristics are strongly positively correlated with each other, except for the hypsometric integral, which exhibits an inverse relationship. As for the correlation between river network properties. Table (10) shows that the number of river orders is strongly positively correlated with the length of river orders and longitudinal drainage density. This is because the number of river orders, which determines the length and longitudinal density, directly affects both properties. The numerical drainage density is also related to the basin's topographic texture with a very strong positive correlation. However, it is inversely related to numerical drainage density: as the numerical density increases, the topographic texture decreases, indicating the fragmentation of the

basin and the degree of proximity and divergence between the watercourses (Ayyana and Muhammad, 1987). Finally, the bifurcation ratio is weakly positively correlated with all properties except for its inverse relationship with numerical drainage density. From the table, it can also be observed that the overall relationship between river network properties is of a varied positive correlation, except numerical drainage density.

Additionally, Table (10) shows that the slope ratio, relative terrain, roughness value, and geometric number share similar relationships with all river network properties, as they are inversely correlated except for numerical density and bifurcation ratio, which exhibit a positive relationship. This means that an increase in the number of river orders in a particular basin may reduce the erosion rate in that basin. This could be due to the distribution of surface runoff across multiple channels, thus reducing the erosive force (Mishra and Pandey, 2014). The inverse relationship between the slope ratio and river order lengths indicates that areas with higher terrain may not support the formation of long river orders. This reflects the impact of steep slopes, which limit the development of river channel lengths. In contrast, the hypsometric integral is positively correlated with all properties except for numerical density. This suggests that areas with a high hypsometric integral tend to have river networks with longer channel lengths. It reflects the influence of rugged terrain on the length of river channels and enhances the likelihood of complex surface runoff patterns in elevated areas, as well as increased surface water flow and soil erosion due to the terrain. Overall, the relationship between terrain characteristics and river network properties is generally inverse, meaning that as the terrain characteristics decrease, the river network properties increase

Table 10: Pearson correlation statistical relationship between terrain characteristics and river network properties of the Al-Amghar basin

	Ruggedness Ratio	Relative Relief	Ruggedness Value	Hypsometric Integral	Geometric Number	River Order	Order Lengths	Drainage Density (Length)	Drainage Density (Numerical)	Topographic Texture	Bifurcation Ratio
Ruggedness Ratio	1										
Relative Relief	0.929*	1									
Ruggedness Value	0.946	0.989**	1								
Hypsometric Integral	-0.881	-0.869	-0.881*	1							
Geometric Number	0.802	0.956*	0.951*	-0.783	1						
River Order	-0.809	-0.779	-0.825	0.964*	-0.731	1					
Order Lengths	-0.819	-0.789	-0.830	0.974**	-0.733	0.999**	1				
Drainage Density (Length)	-0.798	-0.525	-0.567	0.660	-0.285	0.616	0.627	1			
Drainage Density (Numerical)	0.600	0.506	0.433	-0.615	0.268	-0.421	-0.458	-0.675	1		
Topographic Texture	-0.840	-0.812	-0.856	0.971*	-0.761	0.998*	0.998*	0.632	-0.432	1	
Bifurcation Ratio	0.062	0.033	0.124	0.261	0.143	0.143	0.174	0.060	-0.661	0.113	1

*Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level; The pink color represents a very strong to strong positive (direct) correlation; The green color represents a very strong to strong negative (inverse) correlation.

5. Conclusions

The ruggedness ratio of 1.85 reflects the moderate nature of the terrain in the basin. The relationship between area and relative terrain indicates that this terrain value is higher in the third and fourth basins, which are the smallest in area. As for the roughness value, it increases as a result of the increased branching of the river network.

It is observed that the basin is in an advanced stage of the erosion cycle, as indicated by the hypsometric integral. The use of the Strahler (1964) method helped in analyzing the river network pattern in detail, highlighting the role of the terrain in determining the water drainage networks. High terrain values increase the surface runoff within the river network. The total number of river orders reached 7,747 streams with a total length of 5,509 km. The correlation relationship varies, with a strong positive correlation between relative terrain and ruggedness indicating the effect of slope on river network characteristics. An inverse relationship is found between relative terrain and roughness, meaning lower erosion rates. As for river network properties, a positive correlation was observed

between the number of orders and their lengths, while an inverse relationship is found between both longitudinal and numerical density due to the area.

6. Conflict of Interest

The authors declare that they have no conflict of interest.

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تحليل الخصائص التضاريسية وعلاقتها بخصائص الشبكة النهرية لحوض وادي الامغر

جنوب غربي بادية المثنى: دراسة احصائية تطبيقية

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الملخص

يعد حوض وادي الأمغر أحد الأحواض التي تقع في الجنوب الغربي من بادية المثنى. حيث تتميز منطقة الدراسة وبادية المثنى بصورة عامة باستواء سطحها وانسيابها العام وقلة التضرس فيها ويعزى انخفاض الخصائص التضاريسية الى امتداد الحوض الذي يبلغ طوله 85.32 كم مع انخفاض الفارق التضاريسي الى 158 م. وقد أسهم ذلك في انخفاض معدل الانحدار الى 1.85 مما انعكس على الخصائص الرسوبية وسرعة المياه الجارية داخل الحوض. سجل الحوض وجود 7747 مجرى مائياً مما يوضح مدى تأثير هذه العوامل التضاريسية على تشكيل خصائص الشبكة النهرية مثل عدد المراتب، أطوالها، والكثافة العددية والطولية، مع التركيز على تأثير التضاريس منخفضة الانحدار على تشكيل الشبكة النهرية. تم استخدام المؤشرات التضاريسية كالتضاريس النسبية ونسبة التضرس والتكامل الهيبومتري، مع تصنيف المراتب النهرية وفق طريقة "ستراهلر". أظهرت النتائج أن الأحواض الأكبر مساحة تتميز بعدد وأطوال أكبر من المجاري، مع علاقة طردية بين المساحة وعدد المجاري، وعلاقة عكسية بين التكامل الهيبومتري والتضاريس وزيادة كثافة المجاري في المناطق ذات الانحدار المعتدل والصخور الأقل صلابة. كما تبين أن التكامل الهيبومتري ينخفض مع زيادة التضرس.

الكلمات المفتاحية:

الامغر، نسبة التضرس، الشبكة النهرية، المراتب النهرية، بيرسون

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