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Analysis of the Morphometric Characteristics of Wadi Rajil in the Azraq Basin using Geographic Information Systems

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Abstract:- The study aimed to Analyse the Hydrometric Characteristics of Wadi Rajil basin and assess the flood hazards in the basin using Remote Sensing and Geographic Information Systems Techniques. The study used Models of Digital Visualizations of the basin and processed them using ARC GIS 10.5 and ARC HYDRO TOOLS. The result was that the Hypsometric Coefficient reached (21.4%) of the valley area that was exposed to erosion and (78.6%) of it is still waiting for its turn to erosion, indicating that the valley has reached the stage of youth. The analysis of Hot Spots in the GIS program resulted in negative values for internal Drainage Basins greater than -0.5 extending to the northern and northwestern parts of the basin. It also showed that the flow coefficient exceeds the internal Drainage Coefficient or Leakage. As for the positive values, they are distributed in the southern and southeastern parts, where the (Hot) values prevail and where the leakage coefficient exceeds the Flow Coefficient. We find that the Hot Spots are concentrated in the southeastern parts, which are mostly extended. The Rift and thus the most suitable areas for Groundwater Charging through it.

Keywords:- *Morphometric Analysis, Hypsometric Coefficient, Pedestrian, GIS, Drainage Coefficient.*

I. INTRODUCTION

The existence of rivers on the surface of the Earth "dry" begins from a starting point, which is the source in mountainous areas, to end at the mouth in a sea or ocean, covering a distance of thousands of kilometers, passing through mountains, plateaus, plains, wet and dry areas, hot and cold.

Short-flow rivers go through all stages. In mountainous areas, the river may go through only one stage, as the rivers descend from the mountains and are short-flowing and flow into seas, bays or oceans, and are fast-flowing. As for some rivers, they are longer and go through only the stages of puberty and maturity, and the maturity stage is a short distance before the mouth. (Al-Dulaimi, 2017).

Interest in the geomorphology of water basins emerged in the late nineteenth century at the hands of prominent figures, most notably William Davis, who formulated the theory of the geomorphological cycle or the erosion cycle, which gained acceptance and research among researchers. His theory was based on the fact that the geomorphological phenomenon or landform has been variable since its inception, and goes through several stages: childhood, youth, maturity, and then old age. (Abu Al-Ainain, 2004)

The morphometric and hydrological study is related to the water tributaries that affect the water resources that humans need (Bavien et al., 2012), and is also related to the terrain of the place that is formed as a result of the impact and influence of humans within the same space. (Hamid, 2013) Jordan is classified as arid and semi-arid regions, and is considered one of the four poorest countries in the world in terms of water, as the annual per capita share of water is less than (150) m3. The Ministry of Water and Irrigation aims, according to the national agenda, the national water plan, and the water strategy, to raise the annual per capita share to (160) m3, noting that the absolute water poverty line for the individual is (500) m3/year. (Ministry of Water, 2020)

The Wadi Rajil Basin is exposed to annual and recurring floods, which leads to many natural hazards that fall within the areas of urban expansion, roads and agricultural areas, leaving behind many problems that the basin areas suffer from in every influential rainy season, especially in areas exposed to floods near the places of water flow in valleys and low local drains; therefore, this study came to clarify the role of geomorphological studies in assessing the environmental hazards resulting from floods in the Wadi Rajil Basin. (Farhan and Anab, 2016)

II. IMPORTANCE OF THE STUDY

The study will play a role in planning and decision-making processes regarding land management. And building a database that integrates the areas of flood impact and the suitability of lands for different uses, whether current or planned. This is to avoid the severity of the impact of these floods and manage their impact areas to ensure the sustainability of the basin lands for different purposes.

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A. Study Problem

This study focuses on studying the morphometric characteristics of Wadi Rajil, which is one of the valleys of the Azraq Basin east of the Mafraq and Zarqa Governorates. It also focused on producing maps of the drainage network, valley ranks, the main basin, and the sub-basins of Wadi Rajil automatically through the digital elevation model and assessing the environmental risks resulting from floods in Wadi Rajil Basin.

B. Study Questions

- What are the natural and geomorphological characteristics of Wadi Rajil Basin?
- What are the morphometric characteristics of Wadi Rajil Basin?
- What is the relationship between basin variables, to understand the hydrology of the basin, especially surface runoff?

C. Study Objectives

➢ *This Study Seeks to Achieve the Following Objectives:*

- Clarify the natural and geomorphological characteristics of Wadi Rajil Basin.
- Analysis of the morphometric characteristics of Wadi Rajil Basin, relying on geographic information systems techniques.
- Study the relationship between basin variables, to understand the hydrology of the basin, especially surface runoff.

D. Study Methodology

This study relied on the descriptive analytical approach to describe phenomena in terms of their sizes and shapes, especially those whose dimensions were measured, by analyzing the data of the digital elevation model (DEM), to extract morphometric characteristics, as they are considered quantitative geomorphological characteristics, and can be relied upon to create a geographic database for the basin, and then derive water drainage network maps. This network has a relationship in determining the optimal land use in the basin, using hydrological or geomorphological methods, and linking it with geomorphological data based on geomorphological analysis of land surface shapes and the ecosystem in the past and present. In order to understand the causes of discharge and the conditions that lead to its increase in severity and increase the frequency of its impact.

The study used the ArcGIS Version 10.5 geographic information systems software as one of the spatial decision support techniques to prepare a geomorphological map based on the available satellite images of the area from the NASA Earth Data website. And downloading the digital elevation model from the Aster satellite 30 * 30 meters. It also relied on remote sensing technology by downloading the available satellite images of the study area from the US Geological Survey website USGS - Landsat 8 (2020), to extract the vegetation cover index and land uses in the basin.

E. Data Processing:

- Rely on the Digital Elevation Model (DEM) which is downloaded from the website https://earthdatanasa.nasa.gov for analyzing the morphometric area and linear characteristics of the watersheds.
- The analytical part begins with some area and topographical properties of the basin, followed by a study of the water network and its characteristics and watercourses. For the study processing, map projections will be standardized, as a coordinate system that matches the base map was chosen, which is the (WGS 1984 UTM Zone 36N) coordinate system, on which hydrological analyses were conducted. This is within a series of the following procedures:
- The Digital Elevation Model (DEM) file for the study area shows the lowest and highest elevations represented by the terrain in the Wadi Rajil basin.
- Data is processed using Geographic Information System software, by opening the toolbox in (Arc Toolbox) and selecting Spatial Analyst Tools, and then we choose the Hydrology analysis tools, from which we can calculate all the morphometric properties of the Wadi Rajil basin and process the outlier values for the study area.
- Using the (Fill Sink) command from the (Hydrology) menu, which works to fill the depressions and anomalous elevations present in the basin area.
- Determining the flow direction using the (Flow Direction) tool, which aims to determine the direction of flow, and the tool relies on assigning a numerical value to each direction, and so on until the Digital Elevation Model file is converted into a raster file, where each cell contains a value for the flow direction.
- Identifying water accumulation areas (Flow Accumulation), which we use to aggregate flow at each cell by counting the number of cells that will receive water.
- After identifying the watershed of a foot valley, the process of extracting the watercourses within the basin is carried out using the tool (Stream Orders). In this study, the Strahler classification was used to identify the water network and classify it according to different orders, with the ranks appearing within the water network based on the chosen classification.
- After extracting the water network in the study area, we convert the water network from the raster format to the vector format to obtain the lengths of the watercourses, which are used to perform the remaining morphometric analysis of the Wadi Raqel basin.

F. Data Sources

- Satellite imagery ASTER for the year 2013 from the United States Geological Survey NASA.
- SHAPEFILE data from the DIVA / GIS JORDAN website for water basins.
- The remaining measurements were also taken manually according to the previous table (1) by the researchers.

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Table 1: Summary of the Morphometric Equations used in Geomorphological Analysis

The Characteristics. Spatial and Formal.	Variables	Mathematical Relationship.	Source
	Length of the basin (km)	measurement using Arc Map 10.3	-
	Area width (km)	Average basin width = Basin area (km²) / Basin length (km)	(Mahsoub ،2001
	The ratio of basin roundness	Roundness coefficient = Basin area (km) / Area of the circle whose circumference equals the basin perimeter (km²)	(Miller, 1953)
	Shape coefficient	The shape coefficient of the basin = Area of the basin (km²) / Square of the length of the basin (km	(Parveen et al., 2012
	The pelvic elongation ratio	The pelvic elongation ratio = Length of the diameter of a circle whose area equals the area of the pelvis (km) / Length of the pelvis (km)	(Salama, 2004)
Characteristics The network.	Hydrological Order Hierarchical	Classification According to Strahler	Strahler (1964)
	Branching rate	= Number of channels at a certain rank / Number of channels at the following rank	(Al-Dulaimi, 2012)
	Total lengths of waterways (km)	= Total lengths of waterways of the rank / Number of waterways of the same rank	(Babker, 2001)
	River frequency	= Total number of watercourses in the basin / Area of the basin (km²)	**(Ali et al., 2012)**
	Discharge density	= Total length of watercourses of all orders in the basin (km) / Area of the basin (km²)	**(Abdul Aziz, 2000)**
	Intensity of the flow	= Force of the flow / Density of the fluid Di = discharge intensity, Fs = frequency of channels, Dd = discharge density	**(Pareta, 2012)**
Topographical characteristics	Ruggedness ratio	R = Hb / Lb R = the basin's relief, Hb = the difference between the highest and lowest points in the basin (m), Lb = the length of the basin (m)	**(Madment, 1993)**
	Relative topography	= Basin topography (the difference between the highest and lowest elevation in the basin (m)) / Basin perimeter (km)	**(Turab, 1997)**
	The integration of hydrometrics	= discharge density (km/km²) * basin area (km²) / basin topography (m) * discharge density (km/km²)	**(Abouria, 2007)**
	Topographic texture	= Total number of watercourses in the basin / Perimeter of the basin (km)	**(Al-Sahaf, 1985)**
	The value of the roughness	**The value of the roughness = basin topography (m) * drainage density (km/km²) / 1000**	**(Turab, 1997)**

The source is from the work of the researchers.

III. PREVIOUS STUDIES

Numerous studies have addressed one aspect of the topic, and various methodologies and approaches have been employed in the morphometric analysis of the characteristics of the watershed and the risks it faces. It was necessary to mention some studies related to the current research.

The study by Al-Husban, Yusra (2019) titled "Classification of Landforms in the Mujib Valley Basin, Based on the Analysis of Spatial Topographic Indicators and the Production of a Flood Prediction Map," aimed to classify the landforms in the Mujib Valley Basin, as it is one of the most significant canyon-like valleys ending in the Jordan Rift area, where it flows into the Dead Sea at an elevation of -425 meters below sea level. The researcher based his classification of landforms on loading the available digital elevation model with a resolution of 30 meters to derive all the digital maps, and then used the spatial topographic index analysis tools provided by Geographic Information System software, through the following steps: analyzing the spatial slope index, followed by analyzing the spatial topographic index. The most notable results are as follows: 1.According to the spatial regression index, landforms are classified into six types, including: valleys, flat areas, and cliff regions. 2. According to the topographic index, the study area was classified into ten landforms, including: gorges, deeply incised valleys, and plains. 3.There is a strong relationship between the nature of landforms and the risk of flooding, as about 37% of the study area is at risk of severe flooding.

The study by Farhan and Anab (2016) titled "A Remote Sensing and GIS Approach for Prioritization of Wadi Shueib Mini-Watersheds (Central Jordan) Based on Morphometric and Soil Erosion Susceptibility Analysis" aimed to prioritize the watersheds in the Wadi Shueib basin for their

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management and the development of natural resources within it. The land units of the Wadi Shu'ayb basin were classified into four categories: high, very high, moderate, and low. Therefore, the study relied on morphometric analysis and soil erosion analysis to calculate all land units for each watershed in the basin. The study found that (64.3)% of water resources are classified in high and very high categories. By combining morphometric analysis with soil erosion analysis, it was found that most watersheds are classified into moderate, high and very high categories.

The study by Al-Rousan and Al-Qarala (2012), "The Study of the Morphometric Characteristics of the Wadi Shu'ayb Basin Using Geographic Information Systems and Remote Sensing," aimed to produce maps of the drainage network, valley arrangements, the main basin, and the sub-basins of Wadi Shu'ayb through screen digitizing and automatic methods using digital elevation models. In this study, multiple data sources were used, including topographic maps, aerial images, and Landsat and SPOT satellite imagery. Additionally, Geographic Information Systems (GIS) and remote sensing software such as ENVI, ARC VIEW, and ARC GIS were utilized. Maps of the watershed boundaries, drainage network, and river orders were created through screen drawing. The automatic method was also employed to determine the boundaries of the sub-basins, the drainage network, and the orders of the valleys, as well as the slope map and its directions, along with the shaded map. The study results showed a variation in the accuracy of the results in the screen drawing method between the mosaics of aerial images, topographic maps, and satellite imagery from both Landsat and SPOT, due to the discriminatory capability. The results also showed a variation between the screen drawing method and the results obtained using the automatic method regarding the lengths of the drainage network, the delineation of sub-basin boundaries, and the classification of valleys. In addition to the effort and time saved by using the digital elevation model, the study found that the best morphometric characteristics are those that can be derived from the digital elevation model.

The study by Abdullah, Khalid (2009) titled "The Morphometric Characteristics of the Jaukeh Valley Basin and Their Impact on Land Use" aimed to examine the morphometric characteristics of the Jaukeh Valley Basin and their effect on land use. This research was based on the hypothesis that morphometric characteristics have a significant impact on land use.The study relied on scientific research, documents, and official reports, as well as topographic maps and satellite images, to collect, organize, and analyze information. The study concluded that the high degree of ruggedness and the roughness of the area were reasons for the limited spread of residential units in the Jaokh Valley basin. The intensity of water erosion and the roughness of the land have affected the thickness of the soil, and consequently, the area's suitability for agriculture is limited. The increase in the number of river terraces in the Jaukeh Valley has led to the fragmentation of the land into numerous valleys and channels, which has made it more difficult to establish transportation routes and to exploit natural resources within the basin area.

The study by Abu Amra and Hamdan (2010) titled "Some Morphometric Characteristics of the Upper Part of the Rumman Basin in Central-West Jordan Using Traditional Methods and Geographic Information Systems (A Comparative Study)" aimed to highlight the importance of Geographic Information Systems (GIS) software as a means of measuring point, line, and area elements. This was done to calculate the morphometric elements and characteristics of river drainage networks, applied to the upper part of the Rumman Basin in Jordan. Subsequently, a digital information base for the basin was constructed, and this was compared with data derived from conventional methods represented by contour maps, aerial photographs, and fieldwork. The study showed no differences in the measured and derived morphometric characteristics of the basin using both methods, except for the number of first-order tributaries, which increased by 16 tributaries with the new method. This is attributed to the high sensitivity of the software, and this should be confirmed through fieldwork to examine each tributary in nature.

IV. STUDY AREA

Wadi Rajil is considered one of the main valleys located in the eastern and northeastern parts of the Azraq Basin in northeastern Jordan. This area forms the main part of the Hauran volcanic field, which is the largest volcanic field on the Arabian Plate, extending from the southern edge of Damascus in Syria to the east of the Sarhan Valley lowland in the Kingdom of Saudi Arabia. The Blue Basin is a depression formed by a series of tectonic and faulting events, surrounded by mountainous terrain. "Mathnat Rajil" is considered the last gathering place for residents in the northern countryside. This valley is named "Rajal" because it descends from an elevation of 1200 meters to end at an elevation of 550 meters above sea level. This valley descends from the peak of Jabal al-Arab in southern Syria, heading southeast where its journey begins in Jordanian territory in the area of "Al-Muthna." It then flows eastward to cross "Jawa," from which it continues to pour into the basin of "Shabika," nourishing the soil of that basin which continues to host "Rajal" until it overflows and quenches its thirst. The valley then descends southward, passing through some small depressions along the route from Al-Safawi to Ruwaished. After that, it continues its journey southward towards the pond of "Al-Fahdawi," then to the pond of "Al-Malah," where it bends southeast towards the basin of "Al-Muqla." Once this basin is satisfied, it overflows southward to where the Rajal dam was established in the mid-nineties, east of Al-Azraq. Then a man turns after the dam to head west towards the Blue Valley to complete a journey of one hundred and twenty-seven kilometers.(Wikipedia, 2024)

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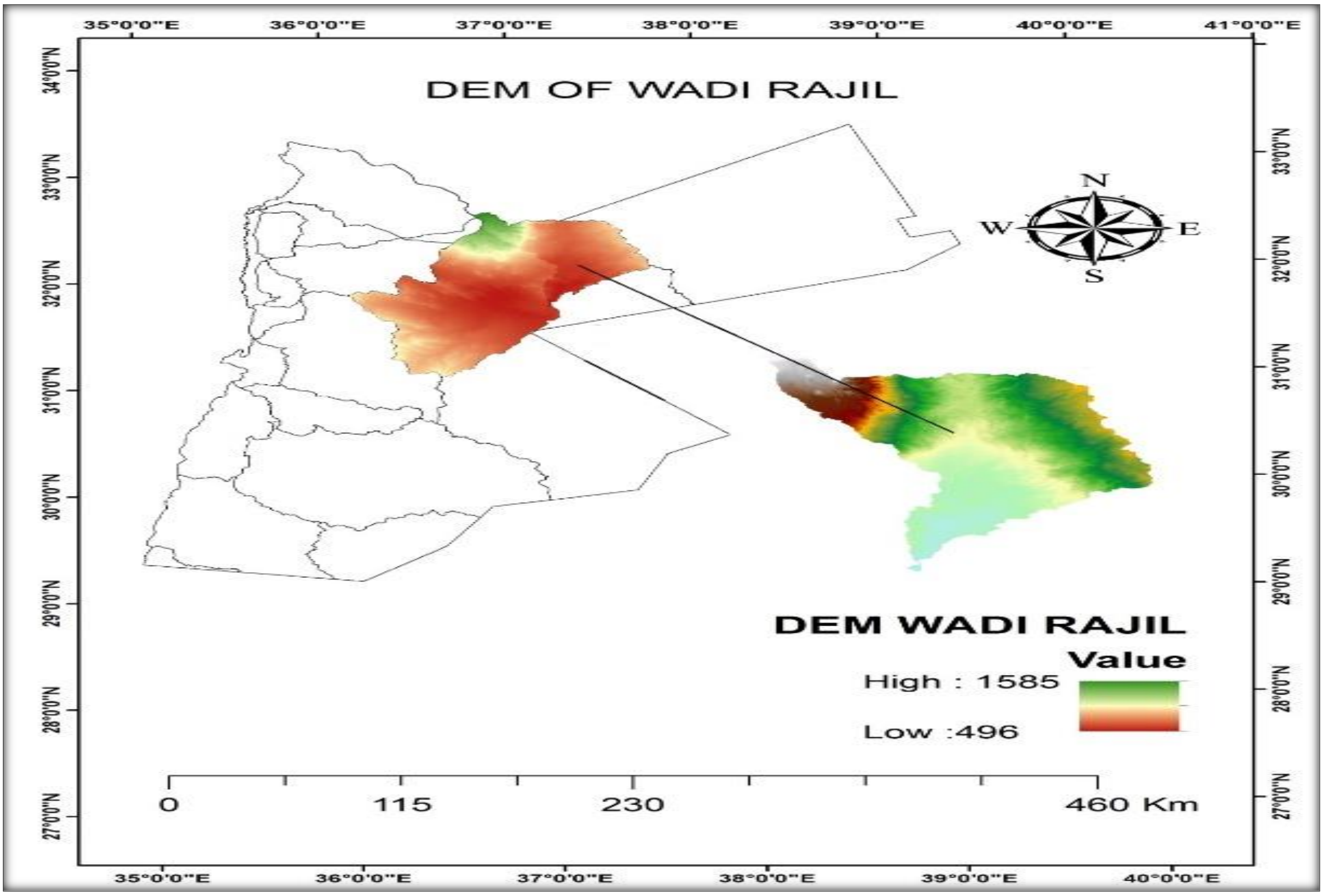

Fig 1: Wadi Rajil in the Northeastern Badia

The source is from the work of researchers using ArcGIS 10.4.

Landsat 8 was relied upon to study vegetation, as it is an important natural element that both affects and is affected by natural and human factors. This was done through analysis and processing using Arc GIS software to extract the vegetation index (NDVI), based on Bands 4 and 5, which help in detecting vegetation cover. The percentage of high-density cover area reached approximately 6.7% of the basin area, while the percentage of medium-density vegetation cover is about 54.3%, which is considered to have a graduated density. While the area of low density accounts for about 39%, table(2).

Table 2: Vegetation in the Wadi Rajil Basin

Percentage (%)	Area (m²)	Vegetation Cover
6.7	234.1	High density
54.3	1901.4	Average density
39	1363.7	Low density
100	3122	Total

The source is based on the work of researchers, relying on Landsat 8 satellite imagery.

It was just as easy to study land uses in the Wadi Rajil basin by relying on satellite imagery data. An unsupervised classification system was followed as a means to aggregate land uses, as there is no familiarity or field knowledge regarding the uses of the basin.

Table 3: Land Uses in the Wadi Rajil Basin

Land Classification	Area km ²	Percentage %
Greenlands	1597	45.6
Barren lands	1382.3	39.5
Salt land	519.9	14.9
Total	3122	100

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The source is based on the work of researchers, relying on Landsat 8 satellite imagery.

It is noted that green land occupies the largest area in the basin, accounting for 45.6% of the total basin area. This is followed by bare land, which covers 39.5% of the basin. The smallest land use category is salt land, which constitutes 14.9% of the total area, Table (3).

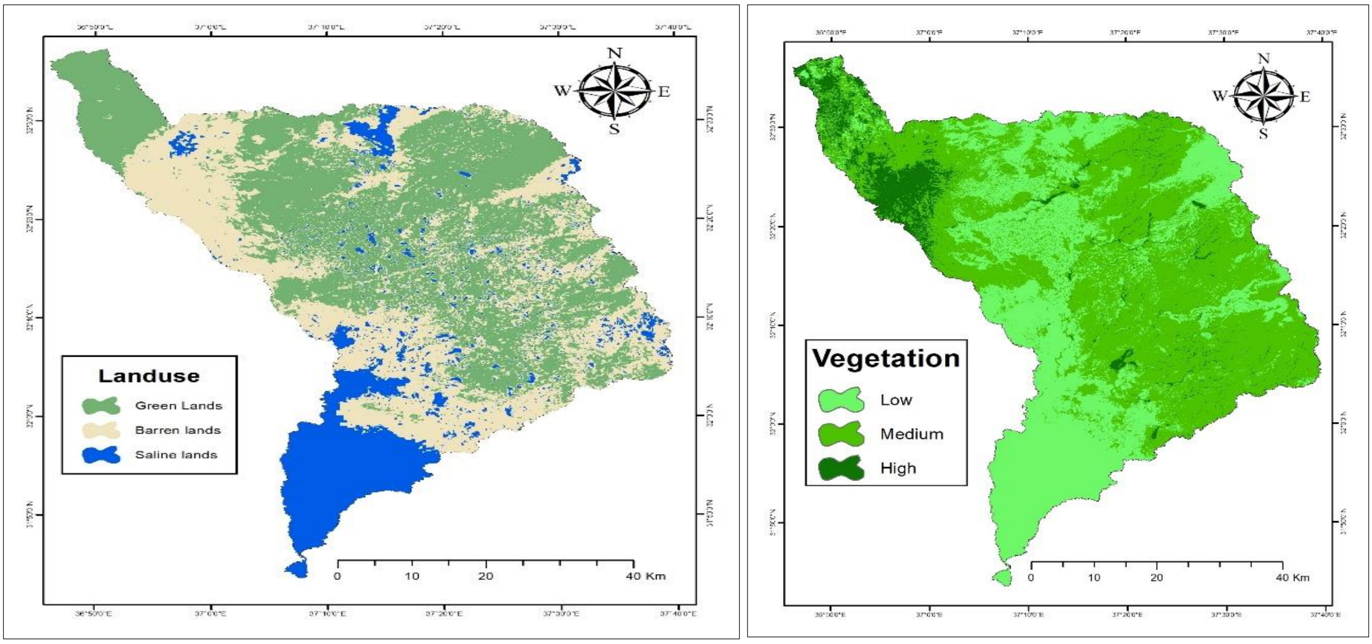

Fig 2: Land Uses and Vegetation Cover of the Wadi Rajil Basin
Source from Researchers' Work

A. Morphometric Characteristics of Wadi Rajil

The table below presents the morphometric characteristics of Wadi Rajil, which covers an area of 3,122 km². This is relatively small compared to other valleys within the Azraq basin, known for its vast area. The basin's area is influenced by various climatic, topographical, hydrological, and geological factors.

The basin's perimeter measures 434 km, which is considered large in relation to its area. The basin's length is 127 km, determined by measuring the linear distance between the upstream and downstream points. The basin's form factor, or circularity ratio, is 0.30, indicating that the basin is not close to a circular shape. This irregularity suggests that the watershed boundaries are not smooth, but instead exhibit significant zigzags. This irregularity is likely due to structural tectonic movements in the area over geological time, along with climate variations and the nature of the rock composition within the basin.

The basin's elongation ratio is 0.25, which is similar to its circularity ratio. This similarity is due to the variation in the valley's width along its length, as the valley becomes more parallel to its width in some sections. The basin's climatic variation is limited as it lies within an arid desert region, where high rates of evaporation and infiltration are prevalent.

Table 4: Morphometric Characteristics of a Pedestrian Valley

Morphometric Variables		
Spatial and Formal Characteristics	Basin Area	3122
	Pelvic length	127
	Basin Width	24.6
	Pelvic Perimeter	434
	Ratio of Rotation	0.27
	Elongation Ratio	0.25
	Basin Shape Coefficient	0.19
Speciality of the water network	River Ranks	6
	Number of waterways	1218
	Percentage of river bifurcation	2.1
	Sewer lengths	2363
	Drainage Density	18.61
	River Frequency	9.6
Terrain Characteristics	Highest Height	1585

	Min Height	496
	Gear Ratio	8.6
	Topographic texture	2.81
	Rugged Value	20.3

Source from the Researchers' Work Based on the Previous Table in the Methodology

The basin shape coefficient describes the regularity of the basin’s width along its length, from the upstream area to the downstream area, with a value of 0.19, indicating that it is closer to a triangular shape. This shape is uneven in width, reaching its maximum width at the downstream area, where it feeds into the main stream. On one side, there are long side valleys, while on the other, the valleys are shorter. This is due to the disparity in rock hardness and resistance, and the basin's location in a dry climate, where the lengths of the waterways are shortened and affected by the limited amount of rainfall.

The drainage density reflects the influence of geological, terrain, climatic, soil, and vegetation conditions on the basin. The drainage density of Wadi Raqel is 18.61, a very high value, which is attributed to the lack of vegetation cover and the fact that it is located in a dry area with hard rock formations.

The topographic texture shows the degree of convergence between the wadis scattered in the basin and helps to assess the intensity of incision within the basin. With a ratio of 2.81 wadis/km, the texture is classified as coarse due to the limited number of valleys on the surface, high evaporation rates typical of dry areas, and the presence of fault lines that allow water permeability and infiltration through rock pores.

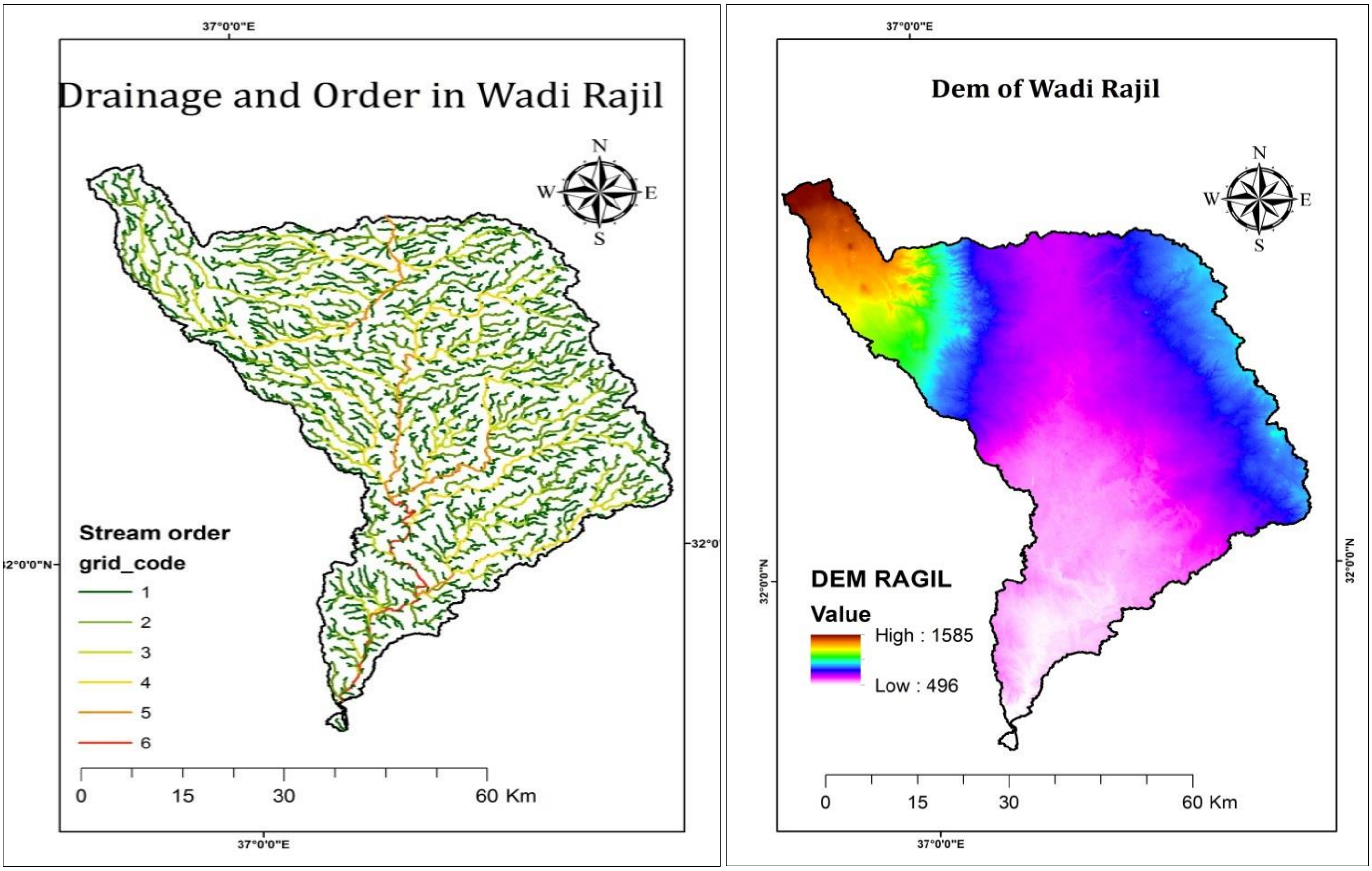

Fig 3: Water Network Characteristics
Source from Researchers' Work Using Digital Elevation Model via ArcGIS10.5

The terrain ratio refers to the amount of sediment transported within the river basin and influences both the volume and speed of surface water flow. It is measured at 8.6 m/km, indicating a medium slope, which suggests significant elevation differences between upstream and downstream areas. The basin is also subject to external factors such as erosion. Figure 2 shows the ruggedness value, which reflects the flatness of the surface. The high ruggedness value of 20.3 indicates minimal erosion due to the hardness of the rocks and high evaporation rates in this dry area. The river system consists of six ranks; an increase in the number of ranks leads to more tributaries, resulting in a wider river and an increased drainage density.

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Table 5: River Ranks, Number of Sewers and Bifurcation Ratio

River Ranks	Number of Sewers	Bifurcation Ratio
6	1	1/26=0.04
5	26	26/115=0.2
4	115	115/120=0.96
3	120	120/306=0.4
2	306	306/650=0.5
1	650	2.1
Total		

The source is from the researchers' work using Excel.

The rate of river repetition indicates an increase of 9.6%, which suggests that the limited number of sewers and their extended lengths contribute to higher drainage density. This increase in drainage density is attributed to the reduced permeability of the rocks and the prevalence of a moderate slope, which is inversely proportional to drainage density. Table 5 shows that the bifurcation rate in Wadi Rajil is 2.1, which falls within the average range of 3 to 5. This average is due to fluctuations in rainfall, resulting in a lower likelihood of flooding under the prevailing climatic conditions.

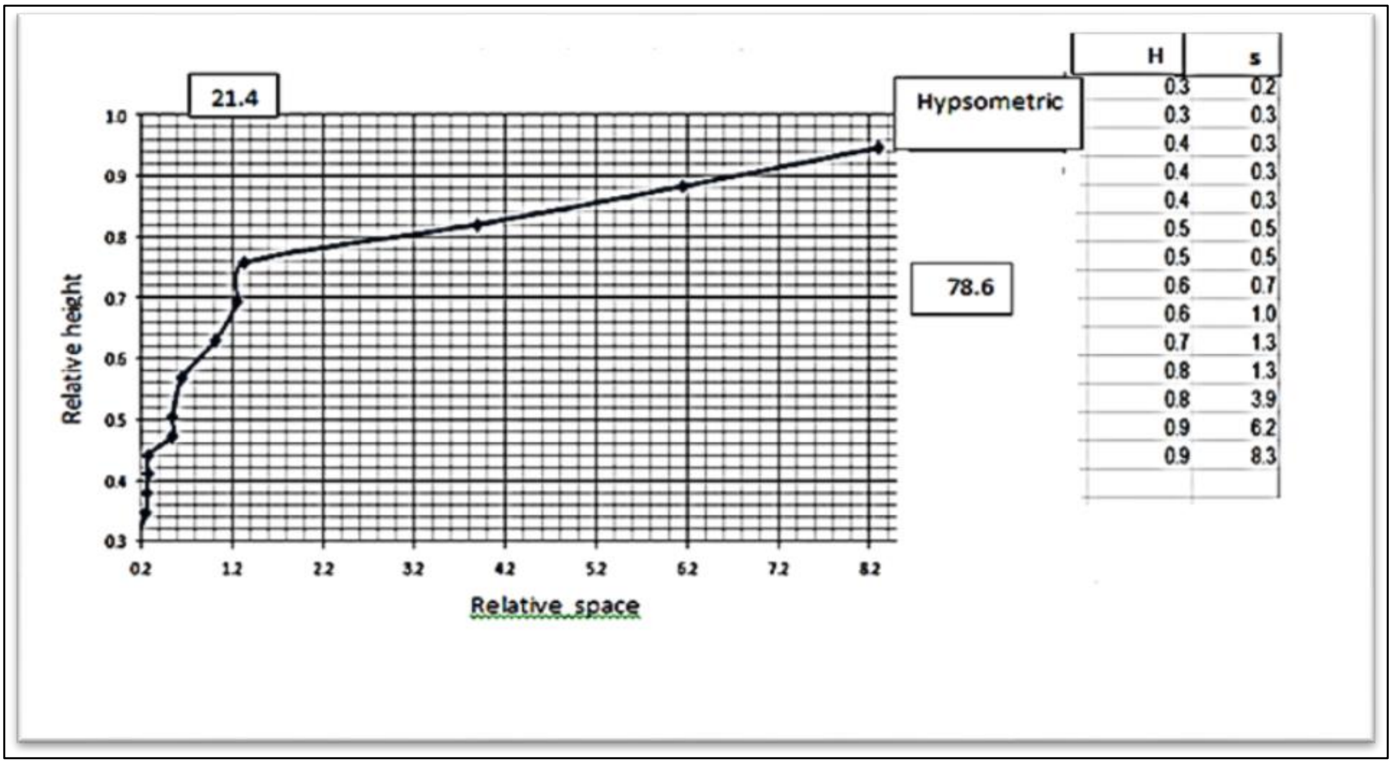

Fig 4: The Hypsometric Coefficient of the Wadi Rajil Basin
Source from Researchers' Work Using Excel Sheet 10

The hypsometric coefficient refers to the ratio between two elements: relative height and relative area (x). It can be calculated after recording the relevant values and drawing a hypsometric curve. The hypsometric coefficient serves as a time scale that reflects the stages that watersheds inevitably undergo, as well as the amount of rocky materials awaiting erosion. Figure (4)

It is evident that 21.4% of the valley's area has been eroded, while 78.6% is still pending erosion. This indicates that the valley has reached a youthful stage. As shown in Figure 5, the slope gradient ranges between 3.6 and 9.9 degrees, indicating a medium slope, which means the stream's length is not extensive. Additionally, the slope orientation towards the southeast and southwest varies from 70 to 287 degrees. This indicates that the basin's topography varies between a relatively flat area at the lower end and a steep gradient at the headwaters.

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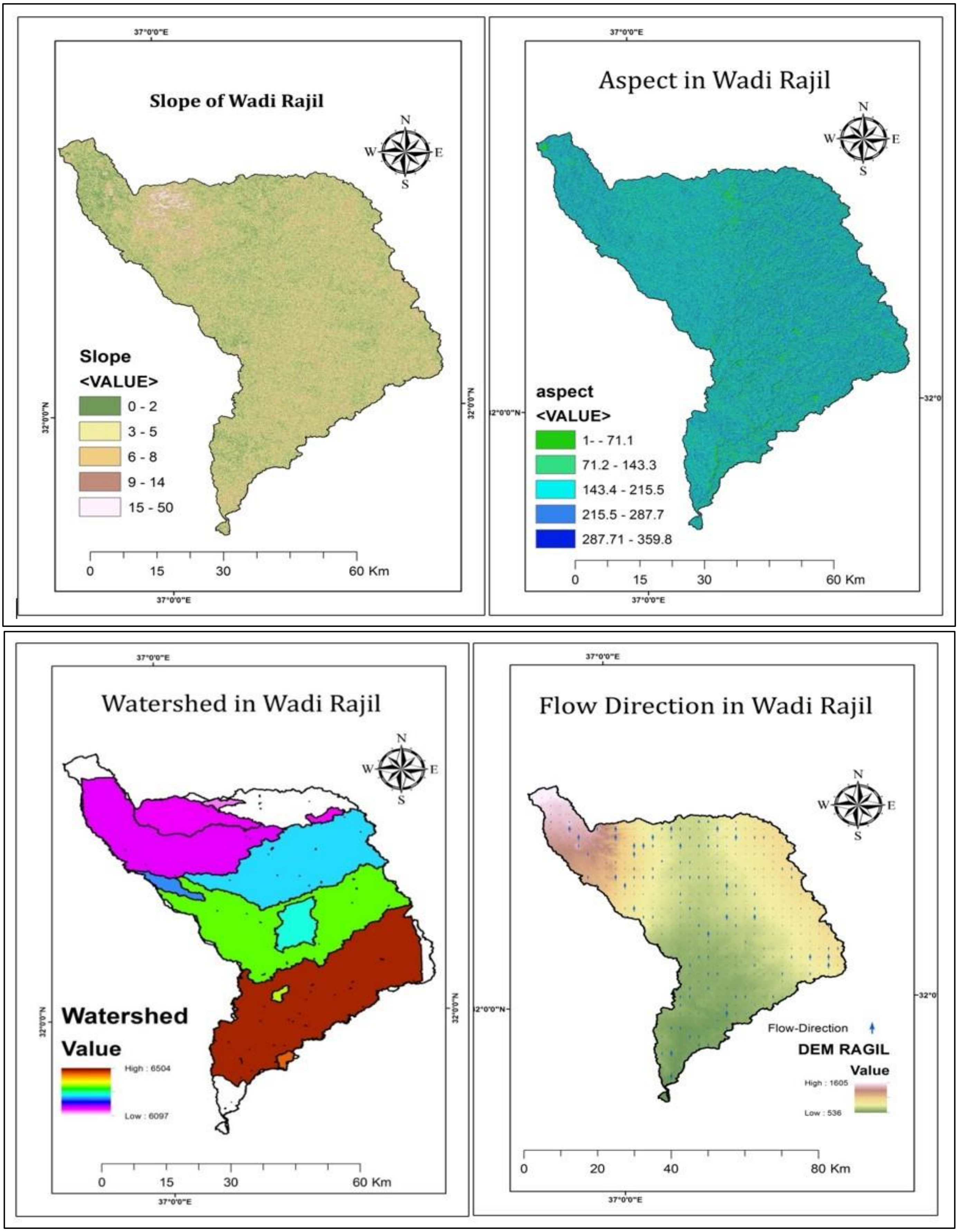

Fig 5: Illustrates the Slope, Inclination, Direction of Flow, and Sub-Basins of Wadi Rajil.
Source from Researchers' Work Using Digital Elevation Model via ArcGIS10.5

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As shown in Figure 5, the direction of flow in Wadi Rajil indicates that the headwaters originate from the northeast in Syria, specifically from Jabal Al-Arab, and flow towards the estuary in the southeast at the Blue Oasis. It was observed that the area of the sub-basins is larger and that their shape is closer to a rectangle in the lower region near the mouth. In contrast, the headwaters are closer to a triangular shape, with a smaller area consisting of sixteen sub-basins.

Figure 5 also depicts the water collection points in the tributaries of the basin, which are distributed randomly and irregularly. A total of 408 internal drainage points have been identified, where 1,218 tributaries or waterways converge. These points are concentrated in the northwestern and southeastern parts of the basin, indicating that the area has rich watersheds.

B. Hotspot Analysis Using GIS 10.5

To verify the internal drainage points, modeling and analysis of these basins were conducted using hotspot analysis, as shown in Figure 6. An effective point analysis was performed using the ArcGIS 10.5 program, which allows for the precise identification of internal drainage basins through the Z-score value and the Getis-Ord Gi confidence level, utilizing the Hot Spot Analysis tool. This tool determines the rate of cold values (negative) in a specific cluster and grades them to identify hot clusters (positive). The analysis revealed that the negative values of the internal drainage basins, which exceed -0.5, are primarily located in the northern and northwestern parts of the basin. Additionally, it was found that the flow coefficient exceeds the internal drainage or leakage coefficient. In contrast, the positive values, which are distributed in the southern and southeastern parts, indicate areas where the leakage coefficient predominates. The hot points are particularly concentrated in the southeastern regions, where the landscape is predominantly fractured, making these areas well-suited for groundwater recharge.

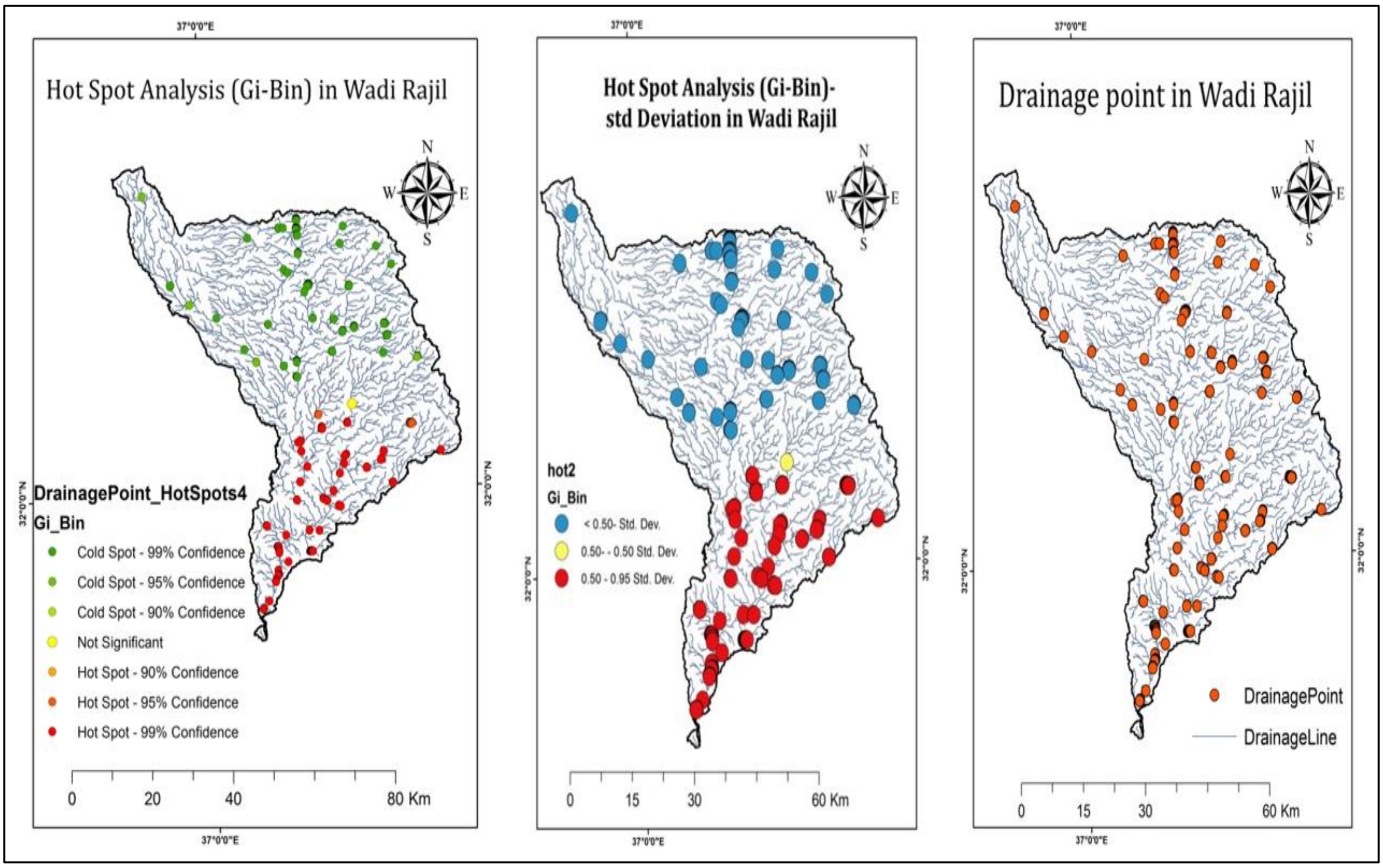

Fig 6: Internal Drainage Basins and Modelling to Analyses the Hot Spots to Clarify the Places of Water Accumulation in the Basin
Note. Source from Researchers' Work

Geomorphological assessment of flood risk for a pedestrian valley. A map was created to measure the susceptibility of floods to the Wadi Rajil basin, based on a matrix that includes the data affecting the occurrence of floods, its degree of severity, and its order of importance, Figure (7), and Table (6).

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Table 6: Classification of Flood Contributing Factors

Nr.	Agent	Subcategory	Sort by impact	Percentage of total	Level of impact per factor
1	Regression	15_50	5	7.25	21.75
		9_14	4	5.8	
		6_8	3	4.35	
		3_5	2	2.9	
		0 _ 2	1	1.45	
2	Regression Direction	1-_71.1	5	7.25	21.75
		71.2_143.3	4	5.8	
		143.4_215.5	3	4.35	
		215.5_287.7	2	2.9	
		287.71_359.8	1	1.45	
3	Vegetation	High intensity	5	7.25	17.4
		Medium intensity	4	5.8	
		Low density	3	4.35	
4	Land Uses	Greenlands	5	7.25	17.4
		Barren lands	4	5.8	
		Salt land	3	4.35	
5	Elevations	1352-1621	5	7.25	21.75
		1084-1352	4	5.8	
		816-1084	3	4.35	
		547-816	2	2.9	
		544-547	1	1.45	
Total		69	100	100	

Source: Researchers' Work

The slope, direction of slope, and elevations significantly impact flood risk, accounting for 65.2% of the total risk. In contrast, vegetation cover and medium-risk land uses contribute to 34.8% of the flood risk (Table 6).

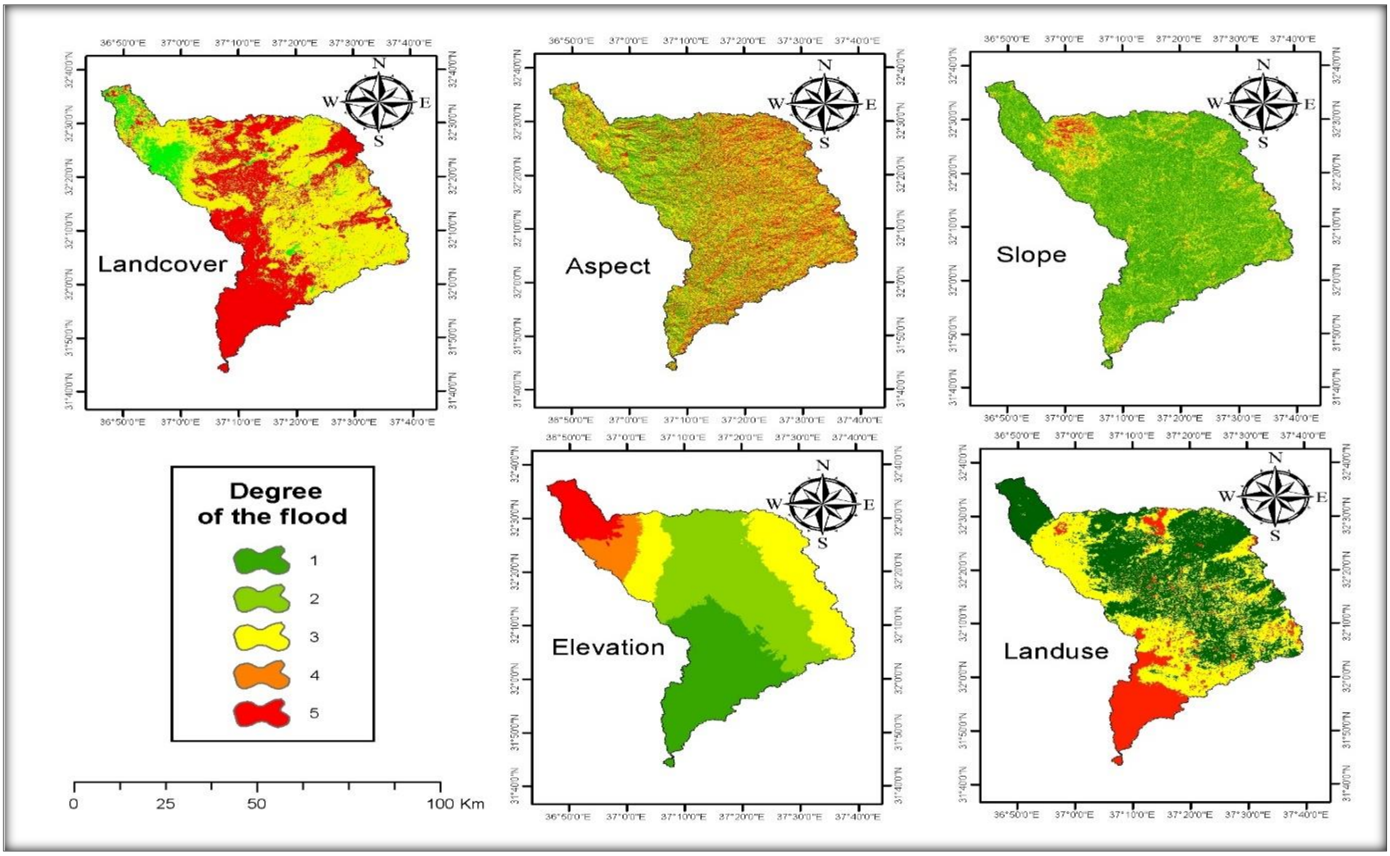

Fig 7: Illustrates the Degrees of Severity of Factors Contributing to Flooding
Source: Researchers' Work

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It is noted that there are significant areas of high flood risk, necessitating the development of technical measures to mitigate flooding and reduce potential damage. Additionally, periodic maintenance of the drainage network is essential.

V. CONCLUSIONS

Remote sensing and GIS technologies play a crucial role in studying the morphometric properties of engineering and mathematical models, facilitating researchers' fieldwork. In this study, modern techniques were employed to analyze the morphology of Wadi Rajil, which is part of the Wadi al-Azraq basin in the eastern region. The turnover ratio was measured at 0.30, indicating a weak resemblance of the valley's shape to a circle, suggesting that the water divides do not follow a regular pattern but instead exhibit clear zigzags. This irregularity is attributed to the structural tectonic movements the valley has undergone over geological time, as well as variations in climate and the rock composition of the basin. The elongation ratio of the basin was found to be 0.25, reflecting a similar trend to the turnover ratio. This result is due to the variation in the valley's width relative to its length, compounded by limited climate diversity, as it is situated in a dry desert region where evaporation and leakage are prevalent. The basin's shape coefficient was calculated at 0.19, indicating that it is closer to a triangular form with varying widths, exhibiting maximum width at the mouth and longer side valleys on one side and shorter on the other. This disparity is due to the varying hardness and resistance of the rocks, coupled with the effects of the dry climate, which results in shorter waterways that are heavily influenced by rainfall.

Additionally, it was found that 21.4% of the valley area has been eroded, while 78.6% is still awaiting erosion, indicating that the valley is in its youthful stage when calculated using the hypsometric coefficient. The internal drainage basins of the tributaries are distributed randomly and irregularly, with a total of 408 internal drainage points where 1,218 tributaries or waterways converge. These points are concentrated in the northwestern and southeastern parts of the basin, indicating rich watersheds in the area.

Hotspot analysis was conducted using ArcGIS 10.5, enabling precise identification of water pooling locations through Z-score values and the Gets-Ord Gi confidence level. The Hot Spot Analysis tool identifies the rates of cold values in specific clusters (negative) and grades them to determine the presence of hot clusters (positive). The analysis revealed that negative values of the internal drainage basins greater than -0.5 are primarily located in the northern and northwestern regions. Furthermore, it was found that the flow coefficient exceeds the internal drainage or leakage coefficient. Positive values are predominantly distributed in the southern and southeastern areas, where the leakage coefficient prevails, indicating that the southeastern regions, characterized by extensive fracturing, are the most suitable for groundwater recharge.

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