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The Morphometric and Hydrological Analysis of the Largest Valley Basin in the Western Plateau of Iraq

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Abstract

The study was carried out to see whether it would be possible to use remote sensing and Geographic Information System (GIS) to create a morphometric geodatabase for the largest valley basin in the western Plateau (Houran Valley), Iraq. ArcGIS V.10.8 measured morphological or hydrological features using a digital elevation model (DEM). These properties are considered a crucial database for planning for dry or wet river basins and valleys, saving time, money, and resources compared to extensive regional research. A quantitative investigation of the morphological characteristics determined that the longitudinal drain density was 0.1698 km/Km^2, indicative of both high soil permeability and an arid to semi-arid desert environment. The basin is in an early geomorphological stage, and the linear structures determined the design of its drainage network according to the circulation ratio of 0.08566. area's geological structure has considerable changes in hardness, as indicated by the elongation ratio of 0.112, which would facilitate the use of water in the process of the area's sustainable development.

Keywords: DEM, GIS, Morphology, Remote Sensing

التحليل المورفومتري والهيدرولوجي لأكبر حوض ووادي في الهضبة الغربية في العراق

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الخلاصة

أجريت هذه الدراسة لمعرفة ما إذا كان من الممكن استخدام أنظمة الاستشعار عن بعد ونظام المعلومات الجغرافية (GIS) لإنشاء قاعدة بيانات جغرافية شكلية لأكبر حوض وادي في الهضبة الغربية (وادي حوران) . استخدم برنامج ArcGIS V.10.8 لقياس السمات الشكلية المورفولوجية أو الهيدرولوجية باستخدام نموذج الارتفاع الرقمي .(DEM) تعتبر هذه الخصائص قاعدة بيانات مهمة لوضع الخطط المستقبلية لأحواض ووديان الأنهار الجافة أو الرطبة، مما يوفر الوقت والمال والموارد عند مقارنته بالبحوث الإقليمية المكثفة .وفقًا لدراسة كمية للخصائص المورفولوجية ، أن كثافة الصرف الطولية كانت 0.1698 كم / كم^2، مما يدل على نفاذية عالية في التربة وبيئة صحراوية قاحلة إلى شبه قاحلة .الحوض في مرحلة جيومورفولوجية مبكرة ، وتحدد الهياكل الخطية تصميم شبكة الصرف الخاصة به، وفقًا لنسبة دوران تبلغ 0.08566 .الهيكل الجيولوجي

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للمنطقة له تغيرات كبيرة في الصلابة ، كما يتضح من نسبة الاستطالة 0.112، وهذا من شأنه أن يسهل استخدام المياه في عملية التنمية المستدامة للمنطقة.

1. Introduction

Morphometry is the topographical expression of the land in terms of its size, slope, shape, length, etc. These features affect watershed stream flow patterns by impacting concentration time [1]. The importance of the landscape factors was previously highlighted [2], who noted that stream flow may be represented as a general function of a watershed's geomorphology. The claim is still valid in light of [3-5] reported that drainage basin geomorphic features play a significant role in regulating basin hydrology. Thus, the morphometric study of basins offers a beautiful depiction of the landscape and a potent tool for comparing the design and operation of drainage basins that may be distant from one another in distance and time [6]. Initially, most basins were classified as well-drained or poorly-drained, categorized using the Davisian scheme as young, old, or mature [7]. Both geologists and hydrologists had only a hazy understanding of the mechanisms governing how river channels form within a basin and how water enters the channels. James Hotton's study from 1775 marked the beginning of measurements and quantitative expression of drainage basins. After that, [8] significantly advanced, consolidating earlier efforts, incorporating fresh measures, and proposing broad approaches defining drainage basin characteristics [7]. Since then, substantial research has been done on mathematical analysis of drainage basins, whether in the temperate zone or the wet tropics [5] and [9]. However, the morphometric properties of drainage basins showed spatiotemporal fluctuation, necessitating detailed examination of basin properties not only from one location to another but also periodically. This is to the basin's shape and morphometric properties dictating the processes. This form-process interaction created a brief impasse in the study of either form or process in geomorphological exploration [7].

Abd Elghany et al. determined the possibility of creating a spatial morphometric database for Wadi Hauran, the largest wadi in the Western Desert. The digital elevation model was utilized to measure the morphological characteristics, whether spatial, morphological, or hydrological. ArcGIS software was used because these characteristics are the important basis for developing future work plans for wet and dry valleys and river basins, which reduces costs, time, and effort to study area [10].

Muhammad et al. adopted different approaches to collecting information, including descriptive, quantitative, and quantitative analytical processes. In particular, the research dealt with the geomorphological characteristics of the selected study area in Kirkuk Governorate. The characteristics of the water network in terms of the direction and pattern of the water basin were determined using a process based on the use of GIS applications. The study revealed that remote sensing was a valuable method for monitoring geomorphological changes and phenomena and land surface shapes, as well as determining dimensions and slopes through analytical maps by geographic information systems [11].

Ahmed et al. used geographic techniques for site selection of water harvesting systems within the Hauran Basin. The Analytical Hierarchy Process (AHP) and pairwise comparison were used to determine the importance of selected water harvesting attributes (area of soil texture, surface runoff, and ground cover). Ninety-six water catchment sites were identified, of which 11 were the most important [12]. The problem statement was studying the hydrological changes and morphological characteristics affecting the study area and knowing the observed measurements by applying the equations of the morphometric analysis of the basin represented by the spatial and morphological characteristics.

The study aims to analyze morphometric and hydrological to measure the engineering characteristics of the earth's surface resulting from the system of erosion in the river and to treat it according to the foundations of quantitative analysis by applying mathematical equations and statistical methods to the data, which were extracted from topographical maps, aerial photographs, and satellite data, in order to use its results in classify the land features and identify the factors and processes responsible for its emergence and development.

2. Location of the study area

Houran Valley is the largest basin in a western plateau, Governorate, Iraq. It stretches 485 km from the Saudi-Iraqi border to the Euphrates River in Haditha, between longitudes 39°13′ 18″ and 42°33′ 47″ east and latitudes of 34°0′ 21″ and 32°4′ 10″ north. The largest of the basins and valleys in the western plateau of Iraq is Houran Valley, which also serves as the primary drainage system. In the far southwest of the region, the Houran Valley begins at Mount Unaizah, which rises 945 m above sea level and passes the intersection of the Iraqi, Saudi, and Jordanian borders [13]. Figure 1 shows the Houran basin on ESRI World Imagery.

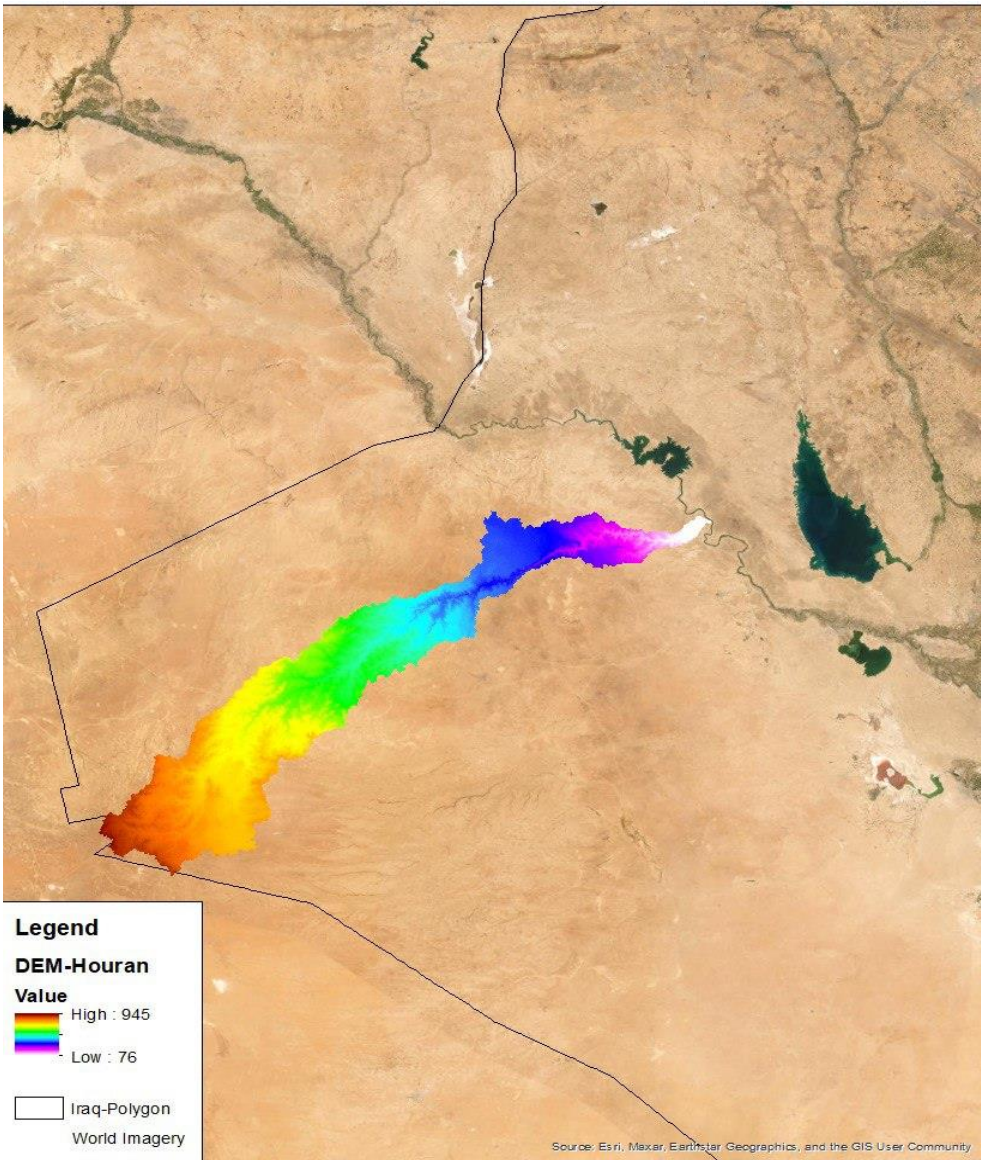

Figure 1: Location of Houran basin in the west plateau on ESRI World Imagery (modified by authors).

3. Methodology of work

The Houran basin of the western plateau was obtained using the ArcGIS10.8.2 program and the Digital Elevation Model (SRTM) with a spatial resolution of 30 × 30 m.

The following diagram shows the steps needed to define morphology-characteristics in the study area:

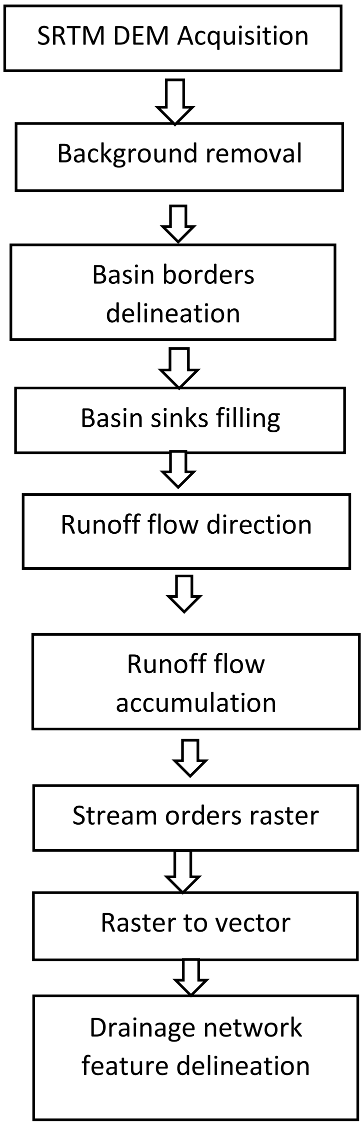

Figure 2: The current work procedure used to define morphology characteristics in the study area.

Using the hydrology option in spatial analysis tools, the stream order, basin drainage network delineation phases, and raster drain network transformation for a vector drainage network were completed, Figures 3 to 6.

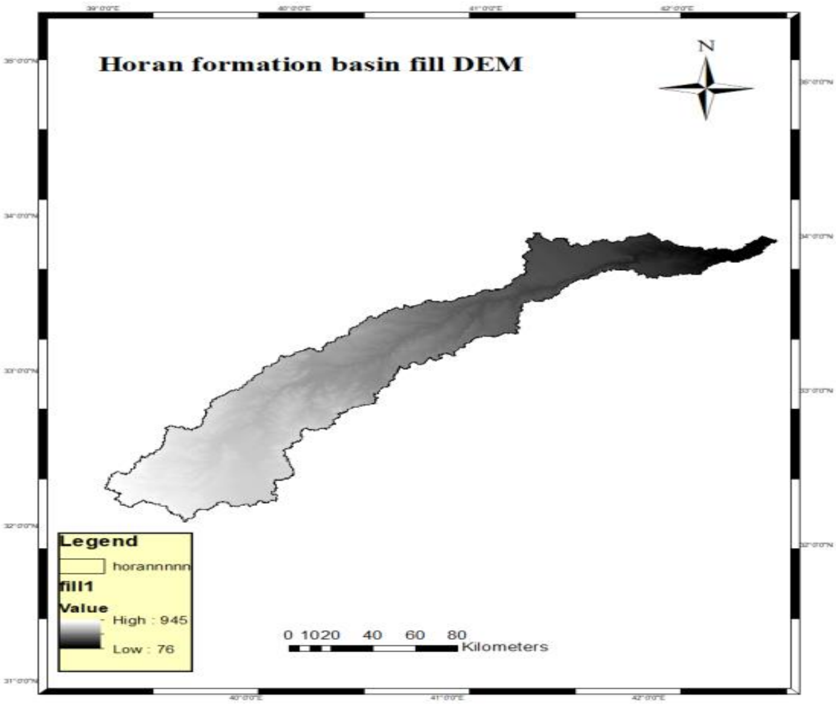

Figure 3: Fill DEM for the Houran Valley basin.

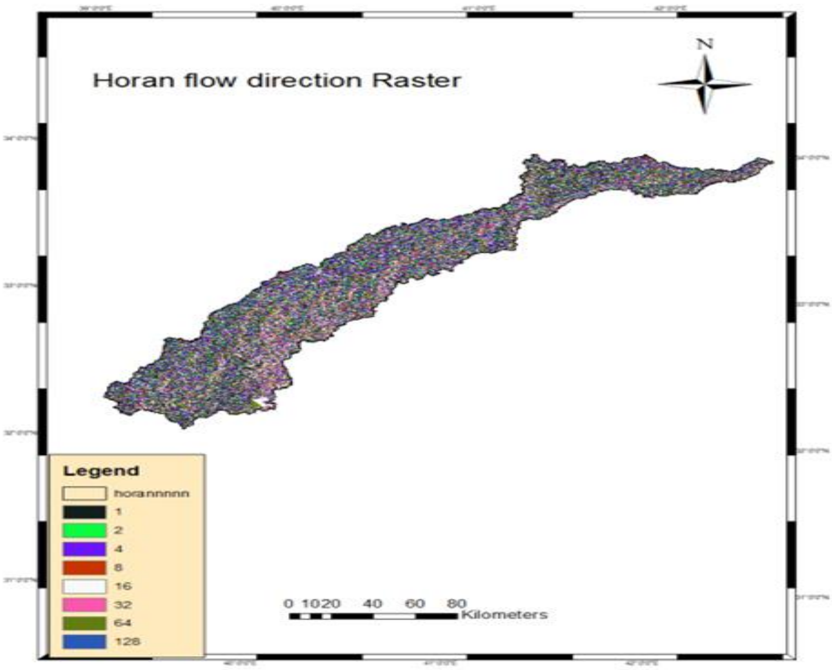

Figure 4: Flow Direction for the Houran Valley Basin.

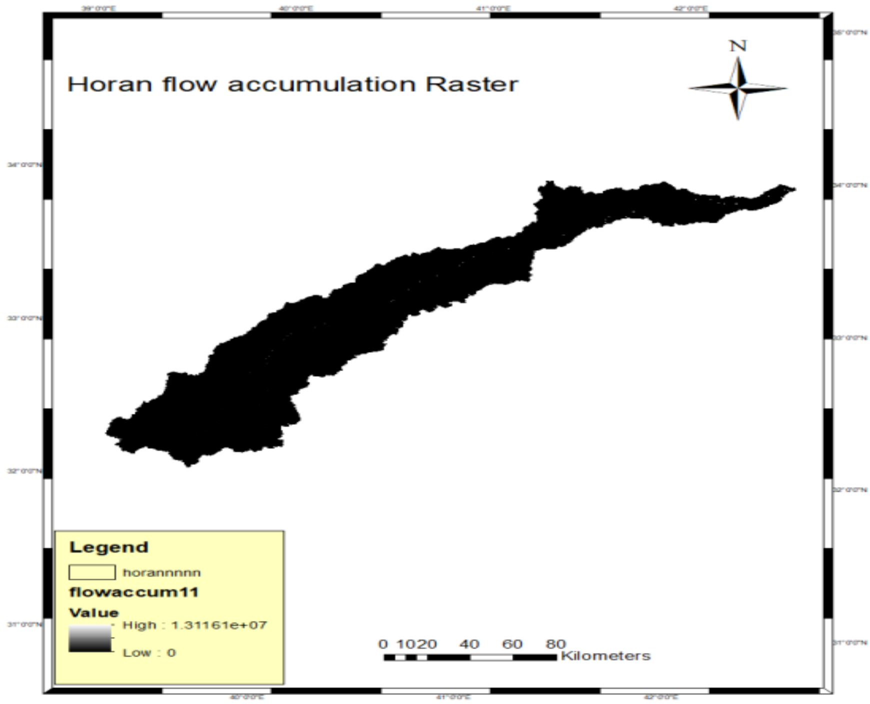

Figure 5: flow accumulation for the Houran Valley Basin.

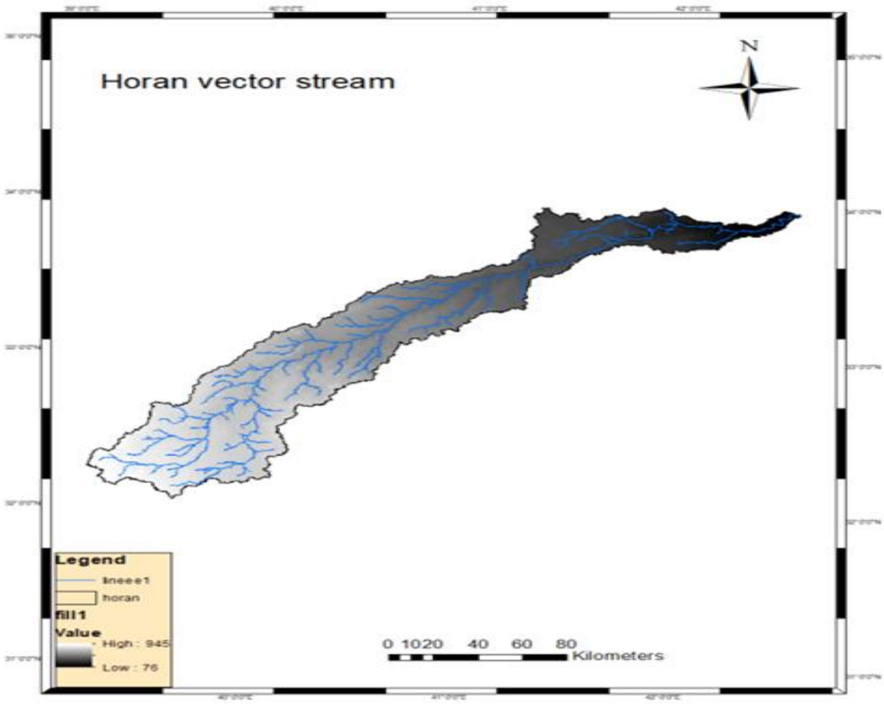

Figure 6: Streams Vector for the Houran Valley Basin.

3.1 Aspect Linear

The one-dimensional linear aspect of a basin is its characteristic. The drainage system can carry water and sediments from the basin through a single outlet; it was designated as the highest-order stream available and is considered for determining the basin's order. The order of the basin has a significant impact on the size of the basin. The following features demonstrated how different morphometric factors signify what they mean physically when used in a GIS setting for the Houran Basin.

3.1.1 Stream Order

Strahler's system of ordering streams is a slightly modified version of Horton's. It was adopted because of its simplicity. In this system, the smallest, unbranched streams were referred to as first order, and two or more of them coming together create a second order, a third order, and so on. A higher order was produced when two channels with different orders collided [5].

3.1.2 stream number (SN)

The total number of segments in each order makes up the stream number. The current research area has a variety of objects, including 3041st-order streams, 131 second-order streams, 60 third-order streams, and 116 fourth-order streams, Figure 7.

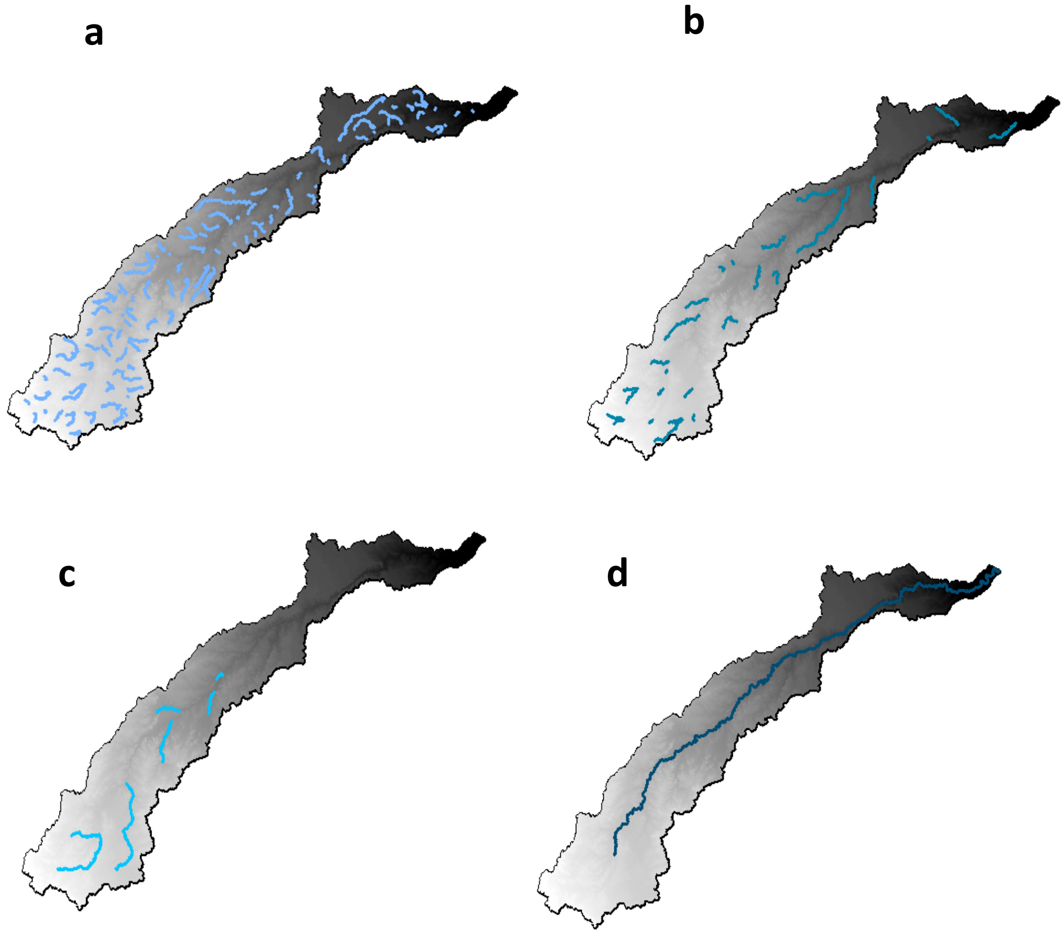

Figure 7: The first-order streams (a), second-order streams (b), third-order streams (c), and fourth-order streams (d).

3.1.3 Stream Length (SL)

The sum of the individual stream segments that make up an order, measured in meters (m), determines its stream length. 1^{st} order SL is 1124289.8, 2^{nd} SL is 456756.63, 3^{rd} SL is 233708.3, and 4^{th} SL is 437752.7 in the hour prior.

3.1.4 Bifurcation Ratio (Rb)

The bifurcation ratio measures how many streams were in one order compared to how many were in the next. The average of the bifurcation ratios of the stream orders within a large basin serves as the bifurcation ratio [13]. Bifurcation ratio affects the amount of flood (i.e., the higher the Bifurcation Ratio value, the greater the risk of flooding in the area, and the opposite is true), the Houran bifurcation ratio (Rb 1^{st} order is 2.3, Rb 2^{nd}order 2.1, Rb 3^{rd} Order 0.5).

3.2 areal aspect

It is the two-dimensional feature of a basin where each stream segment's water supply region can be located. The catchment area can be followed along hillcrests from the upslope source to the junction, where the stream meets the higher-order stream. This line separates the slopes that feed the streams from those that drain into other streams. The maximum flood flow per unit area is inversely related to the basin's size.

The primary calculated areal aspects are as follows:

3.2.1 Density of drainage(Dd)

The importance of drainage density as a topography feature has long been acknowledged. This was due to the drainage density's sensitive nature, which connects many ways between a basin's form characteristics and activities in the stream channel [4]. It also impacts infiltration and the basin's capacity to respond to precipitation before releasing water, in addition to reflecting land use. Geomorphological research is very exciting, especially when it comes to slope development. In a drainage basin, a high Dd value indicates heavy precipitation runoff—however, low-valued Dd results in fewer runoff paths being needed and more precipitation percolating into the earth. Dd can be expressed as a ratio of a basin's surface area to the total length of all its channel segments [5]. It can be categorized into three groups by Strahler, as shown in Table 1. The earth's soil is quite porous since the Houran Dd is just 0.1698 km^{-1}, which is not very large.

Table 1: Drain density classification according to Strahler.

Dd Km^{-1}	explication
3 to 4	little
4 to12	moderate
More than 12	large

3.2.2 frequency of streams (Fs)

Fs and lithological characteristics are strongly related: "FS" refers to the ratio of segments to area. Alluvial plains, on the other hand, frequently have low Fs values, whereas structural hills have high Fs values[14]. The value of 0.046 streams/Km^2 in Houran illustrates the increase in stream population with increasing drainage density.

3.2.3 Drainage texture (Dt)

Drainage texture is calculated by dividing the total number of stream segments in a basin by the basin's perimeter. It is crucial because it affects Marjory's underlying lithology and infiltration potential. Dt was influenced by the region's climate, soil quality, surface terrains, and vegetative cover. Smith divided the drainage texture into five categories: very coarse 2, coarse 2-4, moderate 4-6, fine 6-8, and very fine >8. A basin with a high water permeability indicates a coarse drainage texture, as shown by the Houran Dt value of 0.437 streams/km.

3.2.4 Elongation ratio (R_e)

The ratio of a circle's diameter to its most extended practicable basin length is called R_e. R_e's value spans from zero (when a long basin) to unity (circular). Therefore, the higher the elongation ratio, the more circular the basin is, and vice versa. With R_e values between 0.6 and 1.0, the geological structure solidity of the basins varied significantly [10]. They can be categorized as follows:

Table 2: Re values and their shape-related basin states

R_e	Basin State of shape
<0.7	Elongation
0.7-0.8	Less Elongation
0.8-0.9	Ovality
≥1	Circularly

Houran Re is 0.112 (significant variations in the solidness of their sub-surf structures indicated elongation state).

3.2.5 Rate of Circularity (Rc)

Rc was initially described by Miller as the ratio of the basin's surface area to that of a circle whose circumference is equal to the basin's perimeter. Between 0 (in a straight line) and unity (in a circle), Rc's value ranges. A higher value denotes a more circular basin form, and vice versa. Structure-related restrictions on drainage development are frequently the cause of low circularity ratio values [4]. Lineaments and fracture traces determine the drainage pattern of the Houran formation basin, and its Rc value of 0.085 stream/ Km^2 indicates that it is not spherical.

3.2.6 factor of formality (RF)

The numerical measure known as the "formality factor" [16] categorizes various basin shapes. The value range for Rf spans from 0.1 -to 0.8. The basin will be more extended with smaller form factors. High Rf basins have high peak flows that last for a shorter period, in contrast to stretched basins with low Rf and a lower hydrograph that lasts for a more extended period. Due to their elongated forms, alluvial ones had low Rf or the Houran formation basin; Rf is 0.1.

3.2.7 Number of infiltration (If)

The infiltration number is created by multiplying the drainage density by the drainage frequency [13]. A lower infiltration rate results in greater overland flow water (i.e., developing in draining), lithology is impermeable, and more relief as the infiltration number grows if the value is 0.0078 for the Houran structure basin.

3.2.8 Flow length (FL) of Overland

According to Horton [3], FL refers to the land area before water gathers into distinct channels and runs across the earth's surface. It is comparable to the reciprocal of half of the drainage density. This dramatically affects the water needed to pass a certain erosion threshold. A smaller value for FL implies a well-established drainage system with a steeper slope and speedier surface runoff joining streams. Thus, a considerable quantity of surface runoff contributes to stream discharge. The overland flow has less influence than when it does. The FL of Houran is 2.96.

3.3 Terrain aspects

3.3.1 Relief of Basin (H)

H is the difference in elevation between the lowest and highest points of a valley. Houran Formation Basin is 869 meters.

3.3.2 Relief ratio (Rh)

A basin's height-length ratio, or Rh, can be determined without regard to variations in scale or topography. Rh can be defined as the proportion of the basin's most extended straight line parallel to the main drain channel to the total relief of the basin (H). It controls how quickly the kinetic energy of water draining through the basin is converted to potential energy. Rh represents the erosion process that affects the slope of the basin and is a tangent of the hypotenuse's slope angle about the horizon line. Rh value heightens the relief and steepness of the basin. The Houran form basin's Relative Relief (Rh), which is just 2.37036, is caused by less rosining, fewer sediments, and the peak of a flood in the catchment area[15].

3.3.3 Basin Channel Maintenance constant

The Dd inverse calculates the C value, where watershed cells are required to support a single-channel longitudinal cell. Strongly regulated lithology with a high permeability surface is indicated by a higher value of C. The plain and piedmont zones have the highest values in the alluvial basin; the 5.889 km/ m^2 values the channel maintenance Houran constant[16].

3.3.4 Ruggedness Number (Rn)

Rn is when (Dd) and (H), which share the same reciprocal measurement unit, are multiplied. The roughness number reaches an extremely high value when both variables are large, and the slope is steep. The roughness value for the Houran basin is 0.147.

4. Conclusion

The best method for creating a spatial database for the characteristics of these morphological basins is to analyze the drainage basins spatially using remotely sensed digital elevation models. This allows for a realistic assessment of all environmental aspects of the basins, from soil quality to the region's climate and flood zones, as well as the most effective way to utilize its hydro resources. Houran Basin is a four-ordering basin (304 orders are first, 131 are second, 60 are third, and 116 are fourth). The average Rb value of 1.63, which also denotes modest rosining runoff, demonstrates little concern about flooding in the mainstream in the study region because the soil is sandy (high permeability). Dd is incredibly low (0.1698 km/ Km^2) and represents an arid climate and highly permeable soil in the basin. Due to the high soil porosity in the basin, the drainage texture is particularly rough.

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