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Horan Valley Environmental Monitoring Based on its Digital Elevation Model to the 2023 Year

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Abstract

The ecological interaction, human, geomorphological, and climatological factors lead to basin morphometry; morphometric aspects could be used as evidence for understanding the nature of these factors in terms of active dominant factors within the basin area. Quantitative morphometric analysis based on remote sensing imageries and GIS techniques is the best way to determine these aspects. In this research, a new approach was submitted: using Google Maps to track the Horan Valley path and region that passes through, delineating the main basins in the region, and then neglecting all basins that involve the valley only. The obtained results showed that the Horan region is a four-order basin with 213 1^{st}-order streams, 89 2^{nd}-order streams, 35 3^{rd}-order streams, and 84 4^{th}-order streams, and its area is 12947 km^2, the average bifurcation ratio is (1.784) indicating the flood risk in the basin during rain generally, while the sub-ratios between two successive orders refer to this risk absence in the main order streams. D_d was 0.201 km^{-1}, revealing the area's desertification and increased soil permeability. F_s was 0.0325 stream/ km^2, meaning an alluvial basin formed mainly by sediments during rainstorms. T was 0.0611 $km^{-1,}$ proving the region's soil's high porosity and permeability. R_e was 0.289, indicating semi-rectangle basin shape and geological structures equivalence. C was 0.086, revealing that lineaments control the basin drainage pattern model, and R_f was 0.069, meaning a youth geomorphological stage and length of the water drainage period till arriving at the basin end during the rain.

Keywords: quantitative morphometric analysis, SRTM DEM images, GIS techniques, remote sensing, geomorphology

المراقبة البيئية لوادي حوران استنادًا إلى نموذج الارتفاع الرقمي حتى عام 2023

ليث عزيز جواد
وحدة الأستشعار عن بعد، كلية العلوم، جامعة بغداد

الخلاصة

ان تفاعل العوامل البيئية والبشرية والجيومورفولوجية والمناخية تقود الى شكل معين للحوض ، لذا يمكن استخدام السمات الشكلية كدليل لفهم طبيعة هذه العوامل من حيث العامل السائد وكذلك العامل الذي لا يزال نشطًا داخل منطقة الحوض. يعتبر التحليل المورفومتري الكمي القائم على صور الاستشعار عن بعد وتقنيات نظم المعلومات الجغرافية هو الأفضل لتحديد هذه السمات.

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في هذا البحث تم تقديم نهج جديد باستخدام خريطة جوجل لتتبع مسار وادي حوران والمنطقة التي يمر بها وتحديد الأحواض الرئيسية في انموذج الارتفاعات الرقمي للمنطقة ، ثم تجاهل جميع الأحواض باستثناء الأحواض التي تشمل الوادي فقط.

تظهر النتائج المتحصل عليها أن منطقة حوران عبارة عن حوض رباعي المراتب مع 213 جدولاً من الرتبة الأولى ، و 89 جدولاً من الرتبة الثانية ، و 35 جدولاً من الرتبة الثالثة ، و 84 جدولاً من الرتبة الرابعة ، ومساحتها 12947 كيلومتراً مربعاً ، ومتوسط نسبة التشعب (1.784) مما يشير لمخاطر الفيضانات في الحوض أثناء هطول الأمطار بشكل عام ، بينما تشير النسب الفرعية لمعامل التفرع بين كل مرتبتين متتاليتين إلى زوال هذا الخطر في جداول الرتبة الرئيسية.

D_d هو 0.201 km^{-1} كاشفة عن التصحر في المنطقة وزيادة نفاذية التربة. F_s هو 0.0325 جدولا\ km^2 مما يعني حوضًا فيضياً تكوَن بشكل أساسي من الرواسب أثناء العواصف الممطرة. T هو 0.0611 كم $^{1-}$ مما يثبت مسامية ونفاذية التربة العالية. R_e هو 0.289 يشير إلى شكل حوض شبه مستطيل وتكافؤ التراكيب الجيولوجية في جميع أنحاءه. تشيرقيمة C 0.086 الى أن التراكيب الخطية تتحكم في شكل شبكة تصريف الحوض ، R_f تساوي 0.069 مما يعني مرحلة شباب جيومورفولوجي وطول فترة التصريف للمياه للوصول للمصب أثناء المطر.

Introduction

Accurately extracting the drainage basins' morphometric characteristics has positive repercussions on the realistic analysis of the environmental characteristics of those basins (climatic, topographical, and geomorphological) [1, 2], also in identifying the hydrological indications from an assessment of erosion and sedimentation extent; also estimating the drainage amounts [3, 4] places of occurrence of torrential rains during rainstorms [5], the optimal places for residence preventive dams [6,7], and how to take advantage in farming and grazing [8]. In this research, a quantitative approach was used to extract the morphometric characteristics of the drainage basin of Horan Valley, with the adoption of accurate radar satellite data for altitudes, which are the SRTM DEM data with 90 m spatial resolution per pixel, that is optimum for realistic (not confused) stream drainage pattern delineation. Using different schemes to extract specified morphometric databases, the data integrative principle was used to increase the accuracy and reliability of the measured or computed morphological characteristic before it was included in the database.

Related Works

Ali Dahham Ahmed et al. and Maarez, H.G. [9, 10] studied the geographical procedures utilized to locate the points for surface water harvesting in the Horan Valley basin. The analytical Hierarchy process, added with the pairwise comparative scheme, was used to state the importance of selected traits for harvesting surface water.

Rafiq A., Hajam, et al. [11] studied the possibility of establishing a spatial morphometric database for the Hauran Valley, utilizing DEM for morphometric characteristics, whether cadastral, morphological, or hydrological.

Khamis Naba Sayl et al. [12] utilized the Runoff Water harvesting (RWH) method to achieve eight thematic maps of annual flood volume, basin area, basin length, maxima flow distances, drainage frequencies densities, lineaments frequencies densities, basins slope, and stream order.

L.A. Jawad et al. and Moussa, Y. KH [13, 14] evaluated the effect of the Climatic Quality Index CQI on water harvesting in Iraq valleys.

Problem Statement

The accurate drawing of the water basin boundaries is the basic building block upon which the realistic extraction of the morphological characteristics of these basins was built, and this leads to a reliable analysis of the environmental characteristics of the water drainage basins (climatic, topographical, and geomorphological). Therefore, this work presents a new approach based on integrating geographical data to determine the boundaries of any basin with high accuracy.

Study Area

The Horan Valley is the largest among the Iraq valleys and is located west of the Euphrates River, extending from a point near the border with the Kingdom of Saudi Arabia to its mouth in the Euphrates River. The valley is usually dry except for the rainy season when torrential rains abound. Therefore, there are some primitive dams where the rain levels range between 90 to 120 mm during the rainy season. The valley's slope is smooth compared to its length, where the height difference is 918 m, with a length of 436 km. The valley basin has a considerable area, accounting for 2.9 % of Iraq's total area, Figure 1.

Figure 1: the geographic location of the Horan Valley basin in Iraq.

Analysis Methodology

The structure was formed of four main phases, as follows:

1. Delineate the Horan Valley drainage basin borders.
2. Extract the reliable drainage stream network pattern of the basin.
3. Measure or calculate the aspects of the basin (linear, areal, and terrain).
4. Utilize the quantitative morphometric analysis to reveal basin geomorphological, geological, and climatological characteristics.

1. Horan Valley basin borders delineation

The accurate extraction of drainage stream network patterns and morphometric aspects in any basin depended on the accurate delineation of basin borders; in this research, a new approach was submitted to extract the Horan Valley basin by three steps: the first step is the use of Google map to track Horan valley from its beginning to the end, then identify the region for which it belongs and clip SRTM DEM imagery of it. The second is utilizing the (basin) option in (spatial analyst tool) of ArcMap v.10.5 to delineate the main basins in the recognized DEM region of the traced valley. The third step neglects all basins but the one that involves the valley only.

A. Use of Google map imagery

The spatial resolution of Google map imagery is sufficient for tracking Horan Valley from the beginning to the end and identifying the region to which it belongs. In this step, SRTM DEM imagery of the interest region with 90m resolution was clipped to delineate its possible main basins, Figures (2A) and (2B).

B.After clipping the SRTM DEM imagery of the valley and its neighborhood, the basin option in the “spatial analyst tool” of Arc Map V.10.5 was used to define this region's main basins, Figure (2C).

C.Only ArcMap facilities could extract the basin with the valley passed through it, Figure (2D).

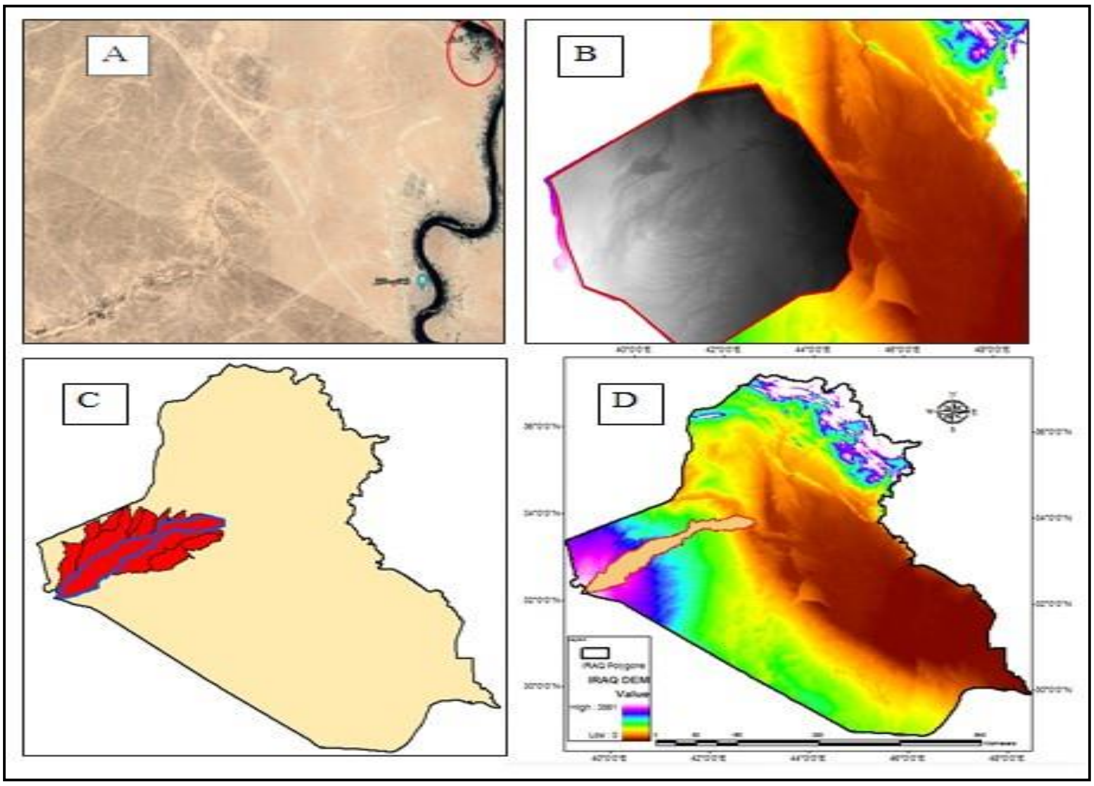

Figure 2: A Google map imagery of the region of interest with the end of the valley identified by a red circle, B. SRTM DEM imagery of the valley and its neighborhood, C. main basins of this region, D. The Horan Valley drainage basin.

Using the “extent” option in ArcGIS 10.5, the basin extends between 39° 17´ 19.37´´E to 42° 45´ 35.5´´E and from 32° 15´ 2.66´´N to 33° 59´ 57´´N with an area equal to12947 km^2, Figure (3).

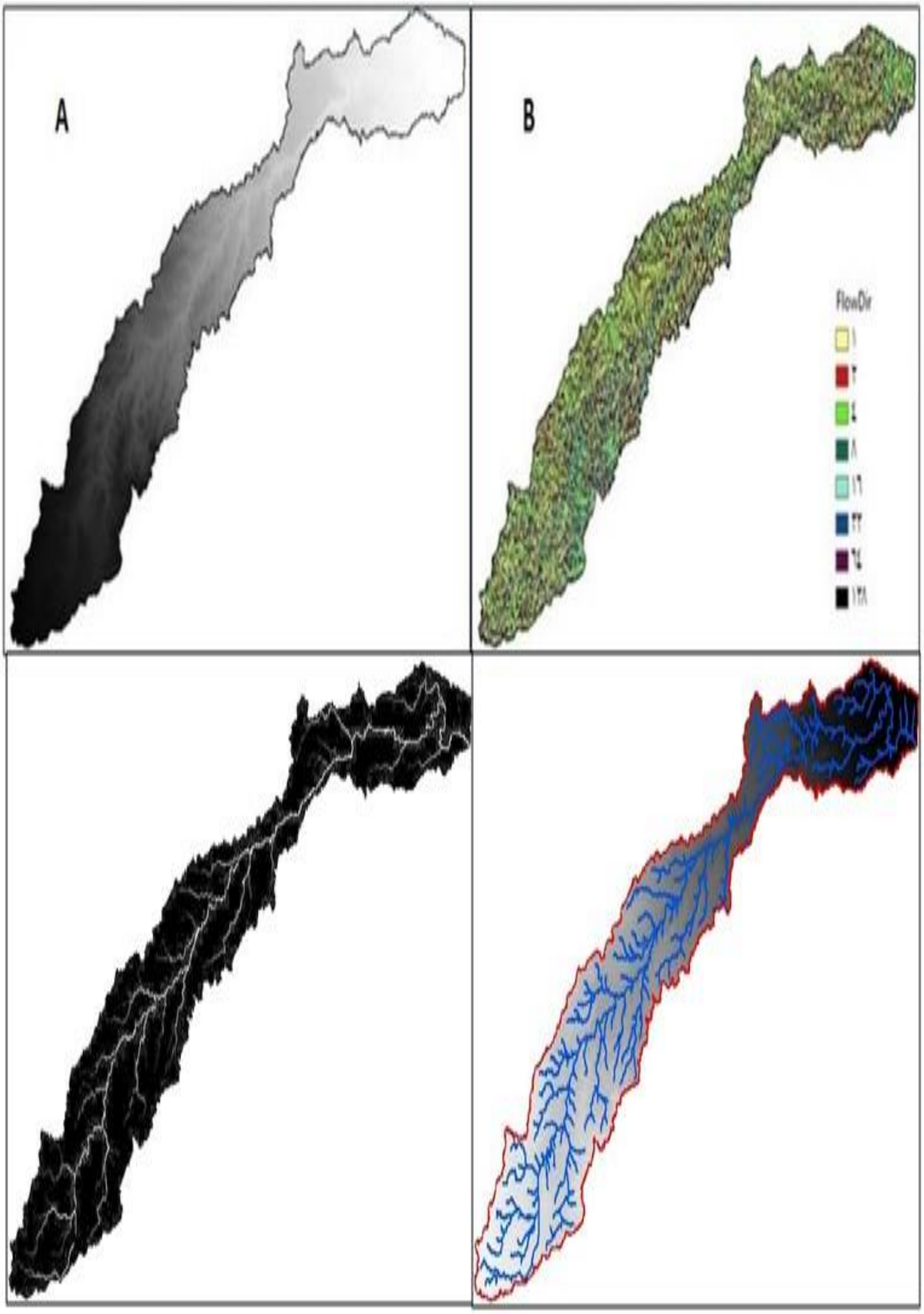

Figure 3: Horan Valley drainage basin map

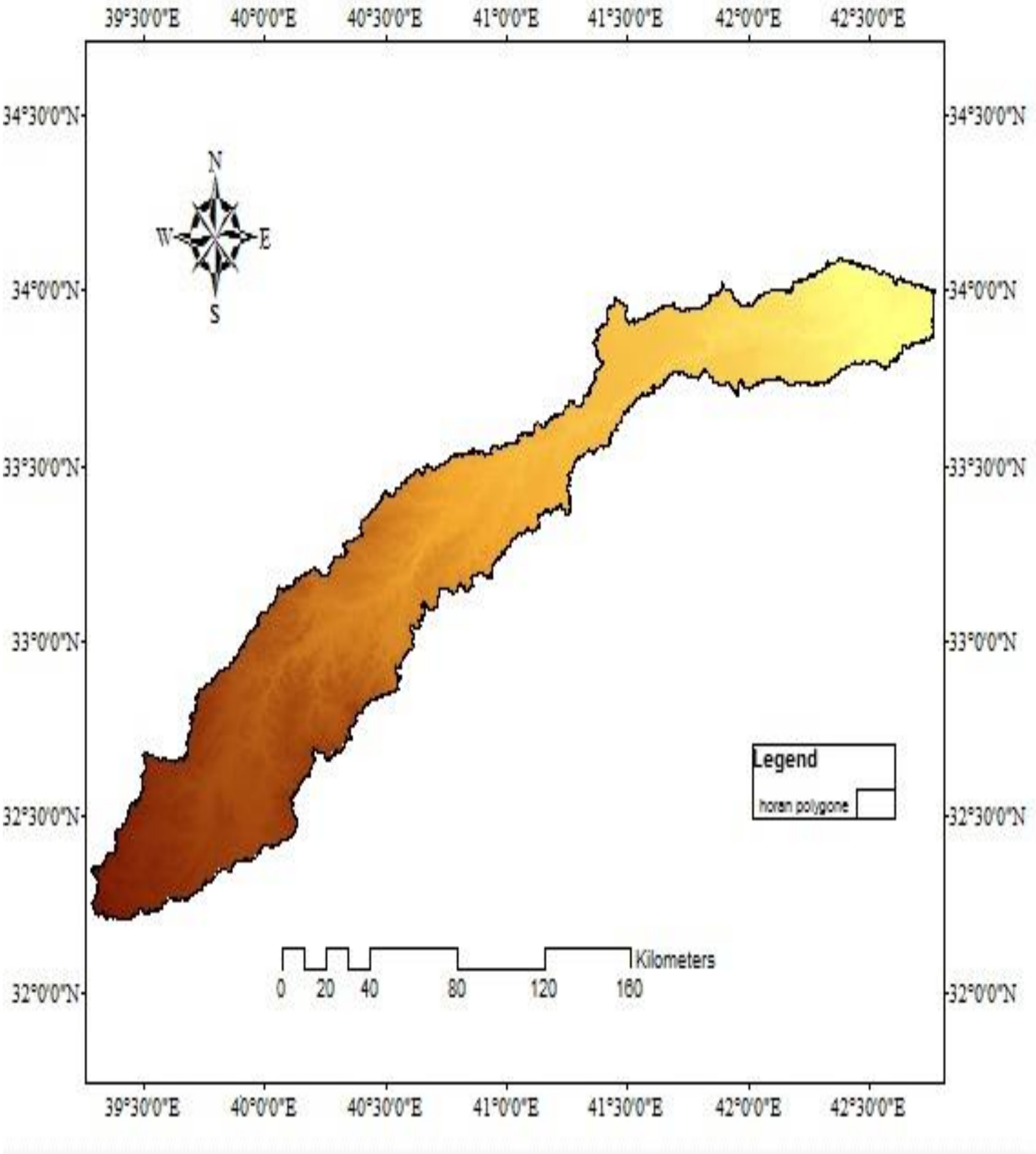

Figure 4: A. filling in the gaps with Horan basin DEM, B. extraction of each cell flow direction in the basin, C. the cumulative value to flow in each pixel, D. most realistic drainage streams model revealing

2. Basin reliable drainage streams and network pattern extraction

The process of extracting an automated model of the river drainage network in water basins is subjected to several stages; when a digital elevation model is used, which fills in the gaps with the picture, it does not contain values. The flow direction would be extracted for each cell in the picture, and then the number of cells that flow into each cell (pixel), i.e., the cumulative value to flow in each pixel, then the most realistic flow model by eliminating cells with low cumulative flux values such as less than 10,000 and finally converting the network from a graphical system to a vector for easy calculations on computer systems, Figure (4).

3. The morphometric aspects measuring or calculating for the Horan Valley basin

Any basin morphometry is the output of many factors" interaction with factor importance ratio (weight in the interaction) that varies from one basin to another. These factors are geomorphological, climatological, ecological, and human. The morphometric aspects can be categorized under three main titles (linear, areal, and terrain). The expert interpretation of those aspects reveals many facts related to basin forming and basin environment and their controlling factors. It is used for basin maturity assessment (whether this area is expanding over time). For the Horan Valley basin, the morphometric aspects were measured and calculated as follows:

Horan Basin linear aspects

The arrangement of basin streams is the first step in hydromorphometric analysis. Horan basin had 213 1^{st}-order streams, 89 2^{nd}-order streams, 35 3^{rd}-order streams, and 84 4^{th}-order streams, Figure (5).

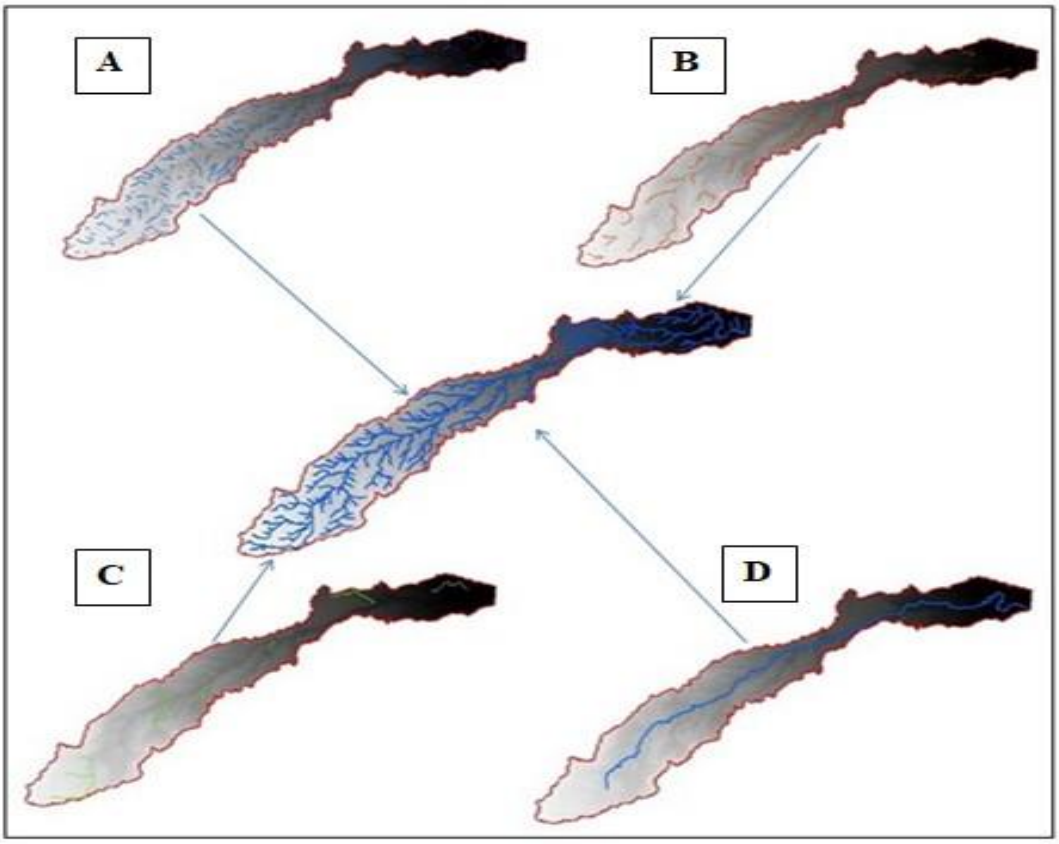

Figure 5: A. Horan basin DEM with extracted 1^{st} order streams, B. Horan basin DEM with extracted 2^{nd} order streams, C. Horan basin DEM with extracted 3^{rd} order streams, D. Horan basin DEM with extracted 4^{th} order streams

In the Horan basin, the length of streams L1 is 281.774 km, L2 is 612.713 km, L3 is 257.488 km, and L4 is 416.136 km. Basin wideness was calculated by dividing the basin area (AK) by its length (LK); the length was 436.02 km, so the wideness was 30.067 km. The Basin perimeter (P) is 1374.614 km. Another linear aspect is the bifurcation ratio; for Horan (Rb1 is 2.393, Rb 2 is 2.543, and Rb 3 is 0.417), the average Rb is 1.784.

Horan Basin areal aspects

In this section, some important areal aspects were calculated as follows:

The longitudinal drainage density of Horan valley basin (Dd) was calculated from equation (1) [3]:

$$D_d = \frac{L_k}{A_k} \ldots.. \quad (1)$$

It was 0.201 km^{-1}.

The numerical drainage density (Fs) was calculated from equation (2) [3]:

$$F_s = \frac{\sum N_u}{A} \ldots.. \quad (2)$$

Where N_u is each order stream number

It was 0.0325 stream/ km^2.

The basin drainage texture (T) was calculated from equation (3) [3]:

$$T = \frac{N_u}{P} \ldots.. \quad (3)$$

It was 0.0611 km^{-1}.

The elongation ratio (Re) was calculated from equation (4) [3]:

$$R_e = \frac{2\sqrt{A/\pi}}{L} \ldots.. \quad (4)$$

Where L is the basin length

It was 0.289.

Horan circulation ratio (R_c) was calculated from equation (5) [3]:

$$R_c = \frac{4\pi A}{P^2} \ldots.. \quad (5)$$

It was 0.086.

Form factor (R_f) was calculated from equation (6) [3]:

$$R_f = \frac{L}{A^2} \ldots.. \quad (6)$$

To be 0.069

Horan Basin terrain aspects

Basin relief is 918 m, and this valley's relief ratio (Rh) is 2.132 m/ km. The Constant of Channel Maintenance (C) is 4.975.

4. Quantitative morphometric analysis of Horan basin

Quantitative morphometric analysis is based on the amount of coefficients and ratios extracted from empirical equations. The value of the coefficient is quantified for several levels, and each level indicates a specific environmental condition in the river basins.

The average branching ratio indicates a risk of flooding in most of the basin area during rainstorms. Likewise, the sub-ratios between every two successive ranks (orders) refer to the same fact for the first and second branching ratios, and for the third ratio, the value determines a large discharge when rain falls in the fourth order of the basin (i.e., the main basin stream) but with no flood hazard since the long course of it that avoid high water peak to be.

The value of the longitudinal density indicates that the soil is highly porous (desert soil). In addition to that, the region has a dry climate for most of the year. The (F_s) value is very low and indicates that the type of basin is alluvial. The texture of the basin, according to the calculated T value, is very coarse (that is, the branches per unit area are few due to the increased permeability of the soil). The elongation R_e is low; thus, the basin is more rectangular than circular, and the hardness of the geological structures is almost the same all over the Horan basin. The value of the (R_c) coefficient indicates that the shape is far from circular and that the linear structures in the basin control the drainage model; this percentage also indicates the stage of geomorphological youth. The calculated value of the (R_f) coefficient indicates the length of the drainage period during the rainwater (i.e., the absence of flooding risk in the main basin stream. The highly valued (C) coefficient reveals the lithological control in drainage patterns and the erosion process's consistency in lower basin areas (basin expansion).

Conclusion

Quantitative morphometric analysis techniques are decisive evidence that does not require long-term field surveys on the environmental characteristics of river basins. Using remotely sensed DEM and ArcGIS environments increased the accuracy of the obtained results. It was found that the studied area falls within the dry climatic pattern, and the longitudinal drainage density coefficient proved this; this climate led to desertification of the area and an increment in soil permeability.

The rain is rare, falling as rainstorms during specific times. However, it does not lead to the occurrence of torrential rain in the basin mouth region, as the form factor value shows an important characteristic is the distance of the basin shape from the circle, which leads to the dispersal of rainstorm water through the basin and the absence of flooding in the main order streams (basin streams), and the branching ratio value also proves this. The characteristics of the terrain have played a key role in increasing the volume of sediments and carving operations in the downstream area, and this was proved by the value of the circulation coefficient, which indicated the geomorphological youth stage of the basin and the geological linear structures control of the drainage pattern in it. The Basin area is highly rosined and continuously expanded, as proven by (C) coefficient.

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