Morphometric Analysis Using Remote Sensing and GIS in the Northern Part of Western Desert, Iraq

Khaldoon Khaled Alwan* **Manal Shakir Ali Al-Kubaisi**** **Nadhir Abbas Al-Ansari*****

***Ministry of Science and Technology/ Space and Communications Department.

****University of Baghdad Iraq/College of Science-Department of Geology Baghdad Iraq

***** Luleå University of Technology/Department of Civil, Environmental and Natural Resources Engineering/Sweden

E_mail: khalidkhaldoon@yahoo.com
nadhir.alansari@ltu.se
Manalshakir@scbaghdad.edu.iq

Abstract

GIS and image processing a great tools for identification of morphometric parameters such as stream length (Lu), stream number (Nu), stream order (Su), bifurcation ratio (Rb), drainage density (Dd), hypsometric integral (Hi), Hypsometric Curve, elongation ratio (Re), circularity ratio (Rc), and form factor ratio (Rf) The Morphometric based GIS was used to analysis a in Northern part of western desert, Iraq the result revealed that, Six Stream order identify in study area with Stream length (Lu) Km and Stream number (Nu) was: 1st order 1670.889 -642, 2nd order -744.559 -166, 3rd order -429.152- 37, 4th order- 302.677- 8, 5th order- 33.795- 2, and 6th order-58.526-1. Bifurcation ratio (Rb) to all stream orders (first to sixth Order) vary between (2- 4.84) with average value 3.79. Form factor is 0.107. Drainage density ranged from 0-4.3 Km/Km². The calculated value for the hypsometric integral (Hi) = 0.45. The elongation ratio of study area is (0.24). The circularity ratio value of the basin is 0.104. Which refers elongated basin in shape with low active tectonic characterizing a mature drainage basin.

Key Words: GIS; Morphometric; Form Factor and Drainage Density.

التحليل المورفومتري باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية في الجزء الشمالي من الصحراء الغربية، العراق.

***خلدون خالد علوان **منال شاكر الكبيسي *** نظير عباس الانصاري**

* وزارة العلوم والتكنلوجيا/دائرة الفضاء والاتصالات

** جامعة بغداد/ كلية العلوم-قسم علم الأرض، بغداد -العراق

***جامعة لوليا التقنية/قسم هندسة الموارد المدنية والبيئية والطبيعية، السويد

الخلاصة

تقنيات GIS ومعالجة الصور الفضائية ادوات مهمة لتحديد المعلمات المورفومترية مثل الرتب النهرية، (Su) عدد القنوات (Nu)، وطول القنوات (Lu), ونسبة التشعب (Rb), وكثافة الصرف (Dd), والتكامل الهيسومتري (Hi), المنحنى الهيسومتري, نسبة الاستطالة (Re), نسبة الدائرية (Rc), ونسبة عامل الشكل (Rf). تم استخدام نظم المعلومات الجغرافية المستندة إلى المورفومتية لتحليل الجزء الشمالي من الصحراء الغربية، وكشفت النتيجة أن، ستة رتب نهرية. حددت عدد القنوات (Nu) مع طولها (Lu) كم: الرتبة الأولى 642-1670.889، الرتبة الثانية 166-744.559، الرتبة الثالثة 37-429.152، الرتبة الرابعة 8-302.677، الرتبة الخامسة 2-33.795 والرتبة السادسة 1-58.526. يتراوح معدل التشعب (Rb) لجميع الرتب النهرية (من النظام الأول إلى السادس) بين 2.0 إلى 4.84 بقيمة متوسطة تبلغ 3.79. عامل الشكل للحوض 0.107. تراوحت كثافة الصرف في منطقة الدراسة بين 0 و4.3 كم / كم². القيمة المحسوبة للتكامل الهيسومتري 0.45 (Hi). نسبة الاستطالة لحوض منطقة الدراسة هي (0.24). قيمة نسبة الدائرية للحوض هي 0.104. الذي يشير إلى حوض ممدود في الشكل مع تكتونية منخفضة وحوض صرف ذو عمر ناضج نسبيا.

الكلمات المفتاحية: نظم المعلومات الجغرافية، مورفومتري, عامل الشكل وكثافة التصريف.

Introduction

Morphometric analysis is quantitative classification and study of landforms as mean in geomorphology that may be employed to a particular type of landform or to drainage basin and generally large area. Morphometry means mathematical and assessment analysis of the arrangement of the earth's surface, dimension, and form of its landforms (Clarke, 1996) most Important principle of morphometry is that drainage basin morphology reflects several geomorphological and geological processes through time, as specific by different morphometric studies (Horton, 1945). Morphometry is highly important in the conception of landform operations and soil properties. Remote sensing the appropriate technique for morphometric interpretation as the images of satellite expand a synoptic view in expanded area and a great help in the analysis of drainage basin morphometry, spatial information technology emerging rapidly, remote sensing and GIS became active tools for morphometric analysis (Rao, et al., 2010). The digital elevation model (DEM) of the study area was used to conclude the morphometric parameters as drainage basin area, drainage density, and stream order, with a collection of the satellite information and hydrological and spatial analysis in GIS conditions (Pirasteh, et al., 2010).

The study aims to employ the GIS and remote sensing applications for analysis in the Northern part of the western desert, Iraq.

Materials and Methods

Study Area

The study area is located within the Western part of Iraq between Latitude of (32°45'0"-34°0'0") North and longitude (39°30'0" – 40°45'0") East as shown in Fig. (1) At Anbar governorate.

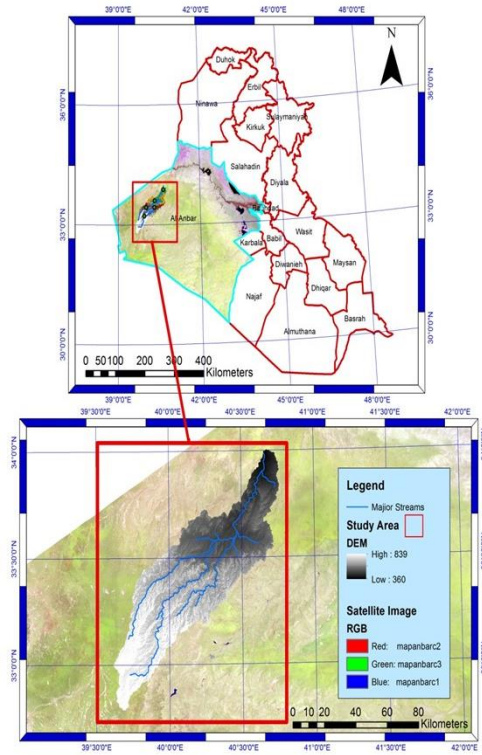


Fig. (1) Study Area.

It overlays an area of 4767.423 Km² with elevation ranges between 360 to 840 m. The elevation of the study area minimizes from southwest to northeast. The climate of the study areas is described by dry, hot summer, cold winter and a nice spring and fall.

About a 90% of the annual precipitation takes place during November to April (generally of it within the winter months from December to March). The remaining six months are dry and hot" (Al-Abadi, 2012). The oldest uncover rocks within the area are of early – late Permian (Ga`ara Formation), whereas the youngest are Early Miocene (Ghar Formation) (Sissakian and Mohammed, 2007).

Morphometric characteristics of the study area were determined by analysis (DEM) using GIS, where the basin area and perimeter were determined, also the stream order, as well as determining the highest and lowest and the average

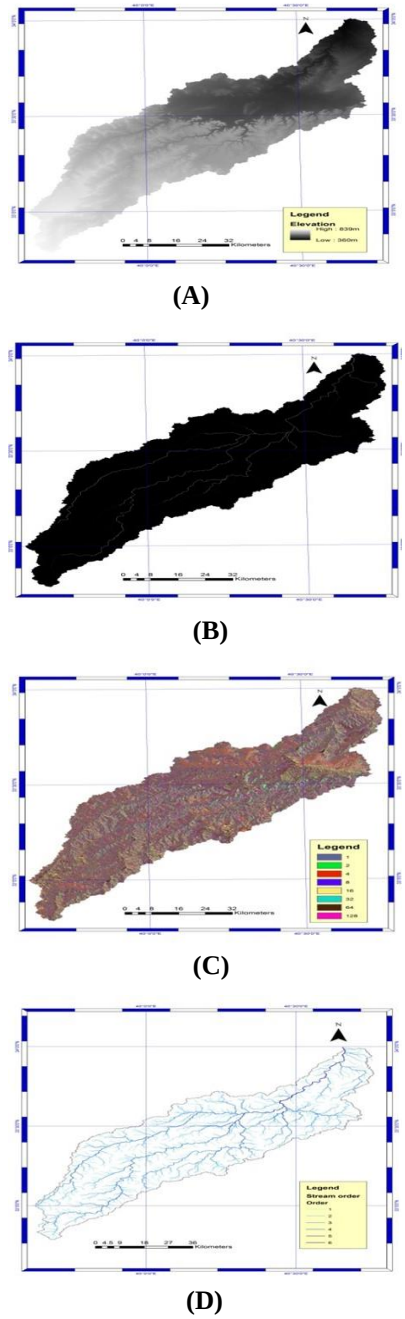
height of the study area. The results were used to calculate these characteristics Fig. (2)

Stream Order (Su)

The identification of stream orders is the first stage in drainage basin analysis. In this study, the number of stream order is carried out using the method given by (Strahler, 1964) the smallest tributaries are set as the order I. Two first-order canals join; a canal segment of order II is created. Where two of order II joins, a segment of order III is created, etc... streams orders for the study area, Table (1) reflects the highest frequency in the case of first-order streams and goes on decreasing as the order of the stream increases, Fig. (3) Mean Stream Length (Lu) Mean stream length is a characteristic referring to the drainage system component and it's linked with basin surface (Strahler, 1964). This is counted by the ratio of a given order's entire stream length to the number of segments streams in the given order. The average stream lengths of the stream increase with the order increase as illustrated in Table (1).

Stream Number (Nu)

The total order of stream segments is called the number of streams. That order's number of stream segments forms an inverse geometric series with order number as shown in Table (1) and as Horton (1945) explained in his study.



(A)

(B)

(C)

(D)

Fig. (2) The Input Variables: (a) DEM (b) Flow Direction Map (c) Flow Accumulation (d) Stream Order Map

Table (1) Stream Order Calculated, Stream length (Lu) km and Stream Number (Nu)

Stream Order (Su)	Stream Length (Lu) km	Stream Number (Nu)
1st order	1670.889	642
2nd order	744.559	166
3rd order	429.152	37
4th order	302.677	8
5th order		33.795
6th order	58.526	1

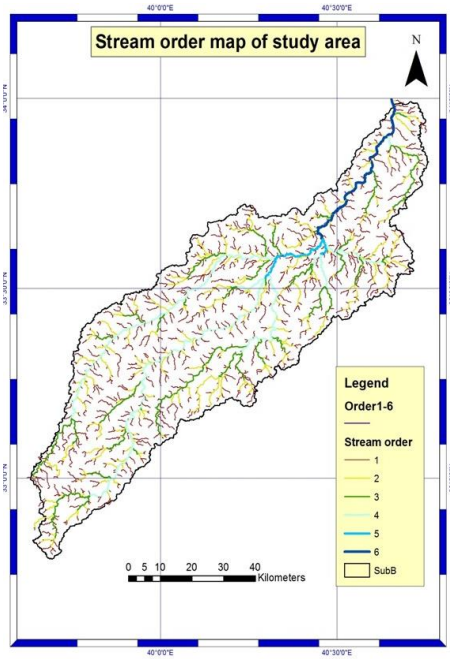


Fig. (3) Stream Order

Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) is the ratio of the number of streams of any given order to that of the number of streams of next higher order (Horton, 1945). Bifurcation ratio ranged from (3-5), Show that drainage pattern does not influenced by the geological structures. The counted values for all orders (first to sixth) extent between (2 to 4.84) with average value of 3.79 (Table 2) which provide us with knowledge that the geological structures in the region have little influence over the whole drainage pattern.

Table (2) Bifurcation Ratio (Rb)

1st order/2nd order	3.86
2nd order/3rd order	4.48
3rd order/4th order	4.62
4th order/5th order	4
5th order/6th order	2
Mean Bifurcation Ratio	3.79

Area (A), Basin length (Lb) and Form Factor (Ff):

The area of the basin is the direct result of the evolution of drainage in a particular basin. Basins are generally pear-shaped in the first stages and evolve to elongate as the cycle progresses. The shape of the basins affected the characteristics of the stream discharge. The basin area is calculated using GIS, which is 4767.423sq Km Table (3). The basin length is the maximum length or the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956). The basins length is 210.232 Km. Another critical parameter recognizes the Form factor as the proportion of the basin area to the basin length square. The amount of shape factor would always be lower than 0.754 (For a circular watershed). The watershed will be extra elongated, the least number of form factors. The watershed with large form factors has high low-duration peak flows, while the elongated watershed has a low form factor. (<0.54) Specifies they are elongated in shape and flow for expanded period too. The drainage basin in study area have form factor is 0.107.

Table (3) Area (A), Basin Length (Lb) and Form Factor (Ff)

(A) (sq. kms)	(Lb) (kms)	(Ft)
4767.423	210.232	0.107

Drainage Density (Dd)

Drainage density (Dd) is a measurement of the whole stream length in a specific basin to the whole area of basin (Strahler, 1964). Elements that rule the characteristic length of the watershed also influence the drainage density. Drainage density in any area related with different characteristics of landscape dissection such as valley density channel head source area, relief, climate and vegetation (Moglen, *et al.*,

1998), rock and soil properties and landscape evolution operations (Nag, 1998) proposed that low drainage density in general take place low relief and bushy vegetation in areas of highly impervious or permeable subsurface soil. The high drainage density occurs in the rocky, porous and impermeable soil mountainous relief and scattered vegetation. The low drainage density area results in a coarse drainage texture whereas high drainage density areas have a fine texture. Drainage density in study area ranged from 0-4.3 Km/Km² (Fig. 4). The drainage density analysis shows that the areas having impermeable material show high drainage density and the areas with low drainage density due to permeability and high infiltration capacity.

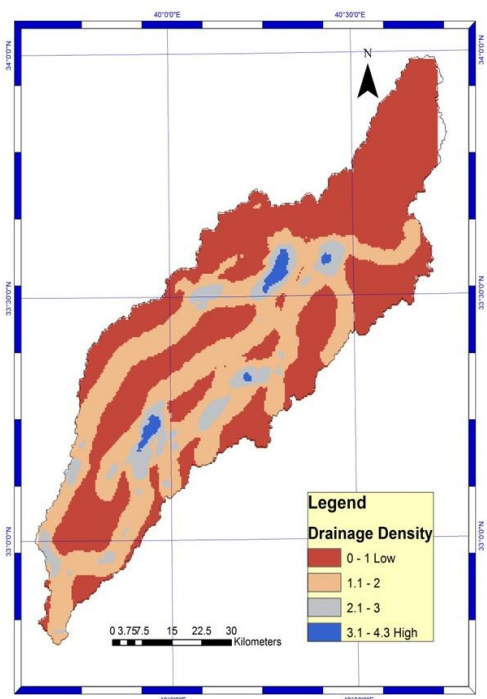


Fig. (4) Map of Drainage Density at Study Area

Hypsometric Integral (HI)

The hypsometric integral (Hi) describes the relative altitude distribution in a given landscape region, particularly a drainage basin (Strahler, 1952). The integral is defined as the relative area below the hypsometric curve, expressing the volume of a non-eroded basin. A simple equation for calculating the index approximately (Pike and Wilson, 1971; Keller and Pinter, 2002) is:

Hi = (hmean – hmin) / (hmax_ hmin)…… (1)

min 40
max 949
mean 44.64
(Hi)=0.45

Intermediate to lower values for the landscape is denuded towards a stage of maturity and old stages (Strahler, 1952; Keller and Pinter, 2002).

In summary, hypsometric integral has shown a strong instrument to recognize the activity of tectonic areas from inactive ones. In the study area, the hypsometric integral shows that the tectonic situation moderate intensity.

Hypsometric Curve

The hypsometric curve is a graph showing the proportion of land area at different elevations by scheme relative area versus relative area, height concept on erosion cycle, and landscape evolution where rivers can be classified according to specific characteristics. This concept categorizes a river as a "Youthful", "Mature" and "Old Age", which Characterizes a mature drainage basin. From Figs. (5) and (6), "the Hypsometric Curve can be described as a Mature River showing a more S-shaped feature and displays a concave upward feature at a higher elevation and concave downwards at lower elevations which characterizes a mature drainage basin" (Keller and Pinter, 1996).

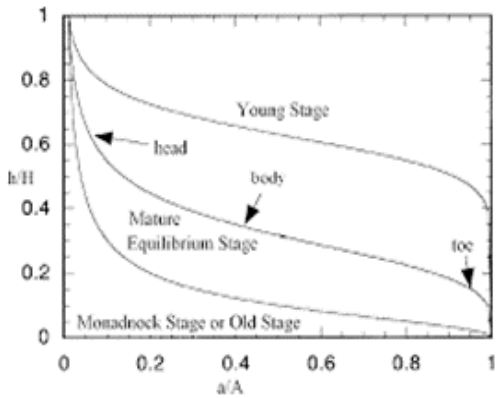


Fig. (5) Interpretation of Hypsometric Curve

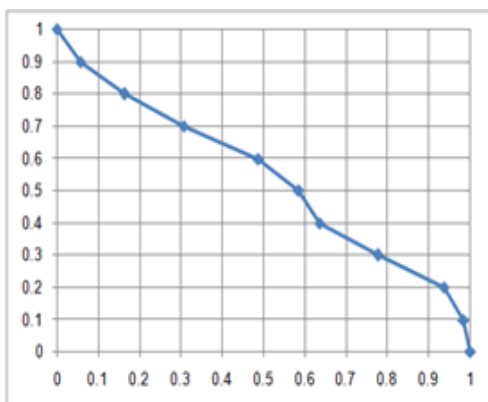


Fig. (6) Hypsometric Curve of Study Area

Elongation Ratio (Re)

(Schumm, 1956) Clarify the elongation ratio as the ratio of the diameter of a circle of the same area as the basin to the maximum basin length. Over a wide range of climatic and geological forms, this ratio ranges from 0.6 to 1.0. Watershed change slopes classified with elongation index support: circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and longer (less than 0.5). The elongation ratio of the study area is (0.24) Which means that the watershed is longer in form with a little active tectonic, related with
steep ground slopes.

$Re=\sqrt{(Au/\pi)}/ Lb$ ……. (2)

A=Area of basin

π=3.14

Lb=Basin length

Circularity Ratio (Rc)

The ratio of circularity used as a quantitative technique, "Defined as the ratio of the basin area to the circle area of the basin with the same perimeter" (Miller, 1953) and it is affected by the lithological character of the watershed. The circularity index varies from zero (as a line) to one unit (as a circle). This ratio marks the stage in which the basins (young, mature, and old) rely on their value (low, medium, and high). (Wilson, *et al*., 2012). The value of the circularity ratio of the basin is 0.104 it suggests an elongated basin in the form of related geological materials.

$Rc= 4\pi A/P^2$……. (3)

A= Area of basin

π=3.14

P= Perimeter of the basin.

Results and Dissection

Remote sensing and GIS techniques are active tools for analyzing morphometric parameters. The study area located in the northwestern desert at Anbar Governorate, the morphometric parameters calculated showing the wide range of differences due to geologically as well as structurally of the study area.

-Six Stream order was calculated in the study area with Length of stream (Lu) km and the amount of stream (Nu) was: 1st order 1670.889 -642, 2nd order -744.559 -166, 3rd order -429.152- 37, 4th order- 302.677- 8, 5th order- 33.795-2, and 6th order-58.526-1.

-The calculated values Bifurcation ratio (Rb) for all orders of streams (first to sixth order) ranges from (2 - 4.84) with an average value of 3.79 which indicates that the geological structures in the area have little influence over the whole drainage system.

-The drainage basin in the study area has a form factor is 0.107 indicates that the

basin elongated in shape and flow for a longer duration as well.

-Drainage density in the study area ranged from 0 - 4.3 Km/Km^2. The drainage density analysis shows that the areas having impermeable material show high drainage density and the areas with low drainage density which is due to permeability and high infiltration capacity.

-The calculated value for the hypsometric integral (Hi) = 0.45 which indicates that the tectonic situation moderate intensity.

-The Hypsometric Curve can be characterized as a "Mature" stream, with a more S-shaped feature and a concave upward feature at higher elevations and concave downward at lower elevations, characterizing a mature drainage basin.

-The elongation ratio of the study area is (0.24) refers to an elongated basin in shape with low active tectonic connected to steep slopes of the ground.

-The value of the study area's circularity ratio is 0.104, which shows the basin elongated with symmetrical geological materials.

References

Al-Abadi, A. M (2012). Hydrological and Hydro Geological of Analysis of Northeastern Missan Governorate, South of Iraq Using Geographic Information System, MSc Thesis, College of Science, Baghdad University, Baghdad.

Clarke, J. I. (1996). Morphometry from Maps, Essays in Geomorphology, Elsevier Publication. Co., New York, 235–274.

Horton, R. E. (1945). Erosional Development of Streams and Their Drainage Basins, Hydrophysical Approach to Quantitative Morphology. Bull Geol Soc Am, 56, 275–370.

Keller, E. A. and Pinter, N. (1996). Active Tectonics: Earthquakes, Uplift, and Landscape, Prentice451 Hall, Inc., New Jersey, 121-205.

Keller, E.A. and Pinter, N. (2002). Active Tectonics: Earthquakes Uplift and Landscape (2nd Edition), Upper Saddle River, New Jersey, p. 362.

Miller, V. C. (1953). A Quantitative Geomorphologic Study of Drainage Basin Characteristics in the Clinch Mountain Area, Virginia and Tennessee, Project NR 389042, Tech Report 3. Columbia University Department of Geology, ONR Geography Branch, New York.

Moglen, G. E; Eltahir, E. A. and Bras R. L (1998). On the Sensitivity of Drainage Density to Climate Change. Water Resource Res 34,855–862

Nag, S. K. (1998). Morphometric Analysis Using Remote Sensing Techniques in the Chaka Sub-basin, Purulia District, and West Bengal. Journal of Indian Society of Remote Sensing. 1998; 26, 69–76

Pike, R. J. and Wilson, S. E. (1971). Elevation Relief Ratio, Hypsometric Integral and Geomorphic Area-altitude Analysis. Geological Society of America Bulletin, 62, 1079-1084

Pirasteh, S.; Safari, H. O.; Pradhan, B. and Attarzadeh, I. (2010). Litho Morphotectonics Analysis Using Landsat ETM Data and GIS Techniques, Zagros Fold Belt (ZFB), SW Iran, International Geo Informatics Research and Development Journal, 6-7.

Rao, N.K.; Swarna, L.P.; Kumar, A.P. and Krishna, H. M. (2010). Morphometric Analysis of Gostani River Basin in Andhra Pradesh State, Indian Using Spatial Information Technology. Int. J. Geomat Geosci, 1(2), 179–187.

Schumm, S. A. (1956). Evolution of Drainage Systems and Slopes in Badlands at Perth Ambos, New Jersey: Geological Society of America Bulletin, 67, 597-646.

Sissakian, V. K. and Mohammed, B. S., (2007). Stratigraphy of the Iraqi Western Desert, Iraqi Bull. Geol. Min. Special Issue, Geology of Iraqi Western Desert, 51- 124.

Strahelr, A. N. (1952). Hypsometric (Area-altitude), Analysis of Erosional Topography. Bull Geol, Soc Am, 63.

Strahler, A. N., (1964). Quantitative Geomorphology of Drainage Basin and Channel Networks, in Chow, Handbook of Applied Hydrology: New York, McGraw Hill, 4-76.

Wilson, J. S.; Chandrasekar, N. and Magesh, N. S. (2012). Morphometric Analysis of Major Sub Watersheds in Aiyar & Karai Pottanar Basin, Central Tamil Nadu, India using Remote Sensing & GIS Techniques. Bonfring Int. J. Ind. Eng. Manag Sci. 2 (Special Issue 1), 8–15.