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Morphometric analysis of Rasyan valley basin - A case study in the Republic of Yemen, using Remote Sensing and GIS techniques

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सार – इस शोध पत्र में अंकीय मानचित्र की विशेषताओं का उपयोग करते हुए आंकड़ा संबंधी सूचना की भिन्नता के कारण उत्पन्न आकृतिमान विश्लेषण के आधार पर भू आकृति विज्ञान के लक्षणों की जाँच करने के लिए सूदूर संवेदी और जी. आई. एस. को अधिक महत्ता दी गई है। इससे दूरी, क्षेत्र, बिंदु, रेखा, बहुभुज और गुणात्मक आंकड़ो जैसे विभिन्न आंकड़ो को प्राप्त करने के लिए आंकड़ा आधारित सूचना को संयत करने में सहायता मिलती है। इससे हस्तानिर्मित मानचित्र के स्त्रोतों के कारण हुई त्रुटियों में कमी आई है। इस शोध पत्र का मुख्य उद्देश्य आकृतिमान विश्लेषण और नदी बेसिन क्षेत्र, बेसिन के आकार, लम्बाई, चौड़ाई और लम्बाई से चौड़ाई तक का अनुपात, परिभ्रमण का अनुपात और बेसिन की परिधि की विशेषताओं का अध्ययन करना है। इसके अलावा ढलान और बेसिन संरचना जल क्वथनांक वक्र जैसे सहायक अभिलक्षणों का भी अध्ययन किया गया है। धाराएँ, धारा–क्रम, लम्बाई, निकासी घनत्व, घुमाव अनुपात, द्विशाखन अनुपात, भारित द्विशाखन अनुपात, निकासी की किस्म जैसे निकासी संजाल के लक्षणों तथा सहायक, जलवायु, मृदा, दूसरे शब्दों में मानवीय प्रभाव के साथ वनस्पति के द्योतक आंतरिक और बाहय कारकों के उपर्युक्त चट्टानी प्रकारों और संचरनात्मक क्रियाओं में उल्लिखित सभी भिन्नताओं के मध्य संबंधों का भी अध्ययन किया गया है। इनसे प्राप्त परिणामों पर लैंडसेट आंकड़ो का उपयोग करते हुए यमन गणराज्य में रासयन घाटी बेसिन के विषय में विवेचन किया गया है।

ABSTRACT. Remote Sensing and GIS has given more importance for investigation of the geomorphological features based on the morphometric analysis duo to the diversity of data information by using digital map characters which help in moderating of data base information to get a different data like distance, area, point, line, polygon and qualitative data. This has decreased the errors which resulted by manual map sources. The main aim of this paper is the study of a morphometric analysis and characteristics of river basin area, basin shape, length, width and the ratio of length to the width, the ratio of rotation and circularity of the basin. It is also a study of relief characteristic, like slope and basin texture hypsometric curve. And also a study of drainage network characteristic like streams, stream order, length, drainage density, turn ratio, bifurcation ratio, weighted bifurcation ratio, type of drainage, and the relationship between all variables that mentioned above with rock types and structural movements of internal and external factors which are represented by relief, climate, soil, type of vegetation along with the human impact on the other hand. Results have been discussed for Rasyan valley basin in the Republic of Yemen using Landsat data.

Key words – Rasyan valley basin, Yemen, Morphometric analysis, Remote sensing, GIS.

1. Introduction

Morphometric studies may be purely descriptive or genetic. Attempts have been made to use the spatial analysis of geomorphic variables to analyze and interpret the landform. To study detailed morphometric characteristics of any river basin area, thorough knowledge of the nature and behaviour of the surface streams in terms of quantity is a very important requisite. Basin morphology controls the basin hydrology and hence it is necessary to understand the development and evolution of the surface streams.

Morphometric analysis using remote sensing techniques has been attempted earlier (Ashor, 1986; Stivastava and Mitra, 1995; Agrawal, 1998, Abo'onaym, 1999; Vittala *et al.*, 2004; Gowd, 2004) and also, the data of Remote sensing and GIS were used for drawing, selecting and modernizing of the river network in the study area and also for analysis of slope, relief and characteristic of river network and the topological relationships between the different phenomena in the study area.

2. Material and methods

The morphometric parameters considered for the analysis are calculated suing remote sensing and geographical information system software

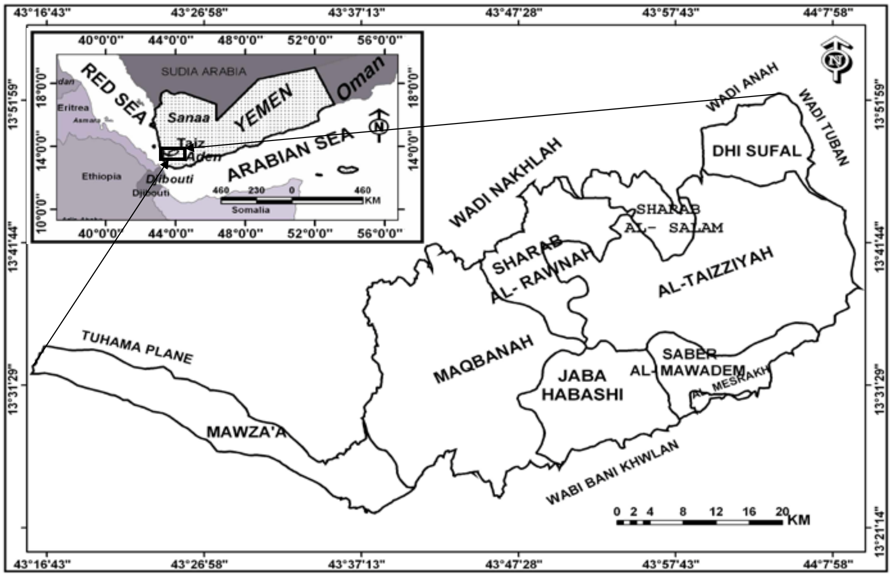

Fig. 1. Location of the study area

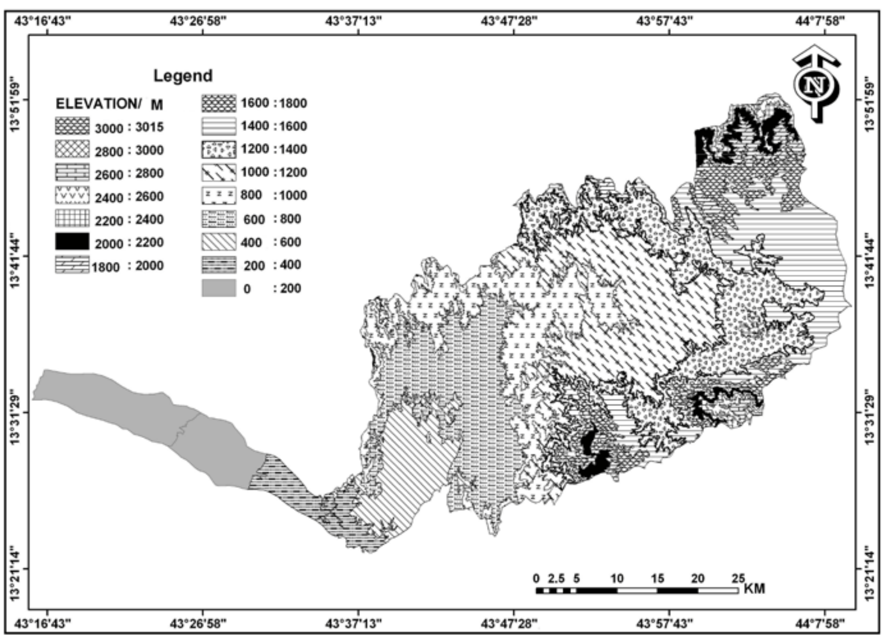

Fig. 2. Physiographical map of the Rasyan valley basin

ERDAS (V. 8.6) AUTODESK LAND DESKTOP 3 (V. 2002), LAND ENABLED AUTODESK MAP 5 (V. 2002) and ARC VEIW (V. 3.2a). For the digitization and computational purpose and for output generation. For morphometric analysis Yemen toposheets bearing numbers 1344 A1, 1344 A2, 1343 D2, 1343 D4, 1343 D4, 1343 B3, 1343 D1, 1343 C2, 1343 A4, 1343 B1 of 1 : 50,000 scale, (Ministry of public works Survey Department Yemen, 1986), have been used.

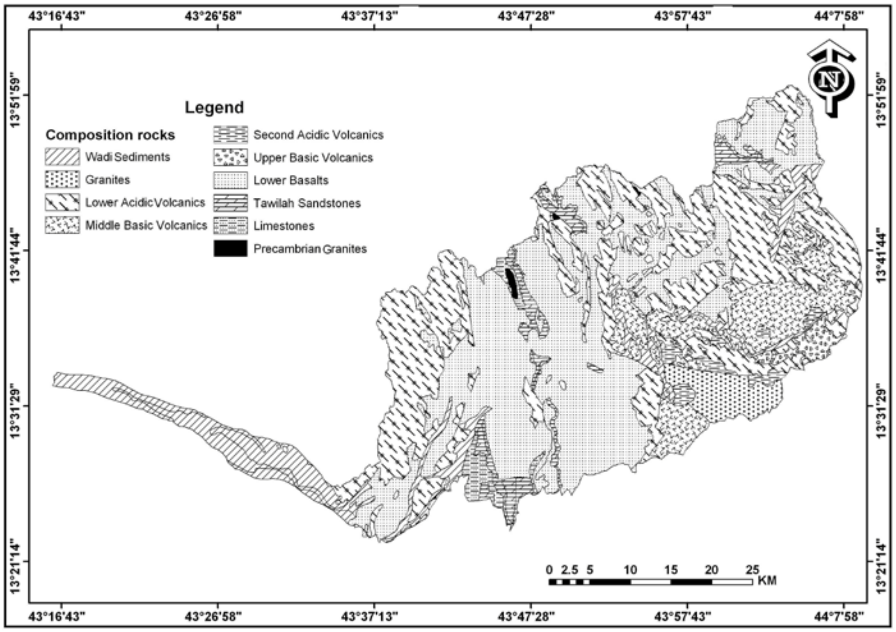

Fig. 3. Geological map of the Rasyan valley basin

The linear measurement was carried out in ARCVIEW. Area measurement was carried out in AUTODESK LAND DESKTOP 3, LAND ENABLED AUTODESK MAP 5 (V. 2002) used topology concept. Elevations within the basin were picked up by toposheets.

Visual interpretation of Landsat TM sensor (28 January 1998, 7 band) merged satellite has been carried out taking into consideration various image and terrain elements. Significant drainage pattern, stream orders classification system. The physiography, drainage density, stream frequency, relief ratio, slope and quantitative morphometric parameters of the drainage basin are the variables used satellite data and digital elevation model of the study area.

2.1. *Location and area*

Rasyan valley basin is located in the western part of Republic of Yemen between the 43° 15′ 32″ - 44° 10′ 13″ Longitude and 13° 10′ 13″ - 13° 51′ 46″ Latitude. The study area is determined from north and north-east by basin of Wadi Tuban, basin of Wadi Anna’h and basin of Wadi Nakhlah from north and north-west and the read sea from west and Wadi Bani Khwlan basin from south and from western parts of Red sea (Fig. 1). Rasyan valley basin is covered 1896 km^2 (Yemen topographic sheets, 1986 and Landsat data, 1998).

2.2. *Topography and geology*

The morphology of basin formed from zero state at Red sea coast level in the eastern of the basin and 3015 m above that level on Alaroos crest in Saber Mountain, (Fig. 2). The topography of this area contains Series of Mountain at north and western parts. Whereas the internal parts, few of mountains, plateaus, hills and deltas of rivers are noticed in the western part is desert in the area. The rock types can be divided into four groups, old rocks which refers back to Precambrian age (igneous, metamorphic and metasediments) and before and these kind of rocks available in northwest (Al-kherbash and Al-Enbawi, 1996), also sedimentary rocks which refers back to Jurassic (limestones, bituminous, marls, conglomerate and dolomites) and cretaceous (hard argillites, cross-bedded, bioclastic sandstones, yellow sandstones and dark red sandstones) age and these rocks exist in northwest and southwest, volcanic rocks (granites, basalts, trachy-andesites, thyolites and pyroclastics) which represent almost of the rocks in this area which refers back to Tertiary age (Nickolay *et al*., 1997; Dar El-Yemen, 1997). The Quaternary deposit (sand, gravel, loam, loess, clay, conglomerates, sabkha, deposits, marine shell and reef deposits) are which cover whole internal hills, plateaus in the middle and west parts of the basin, (Fig. 3).

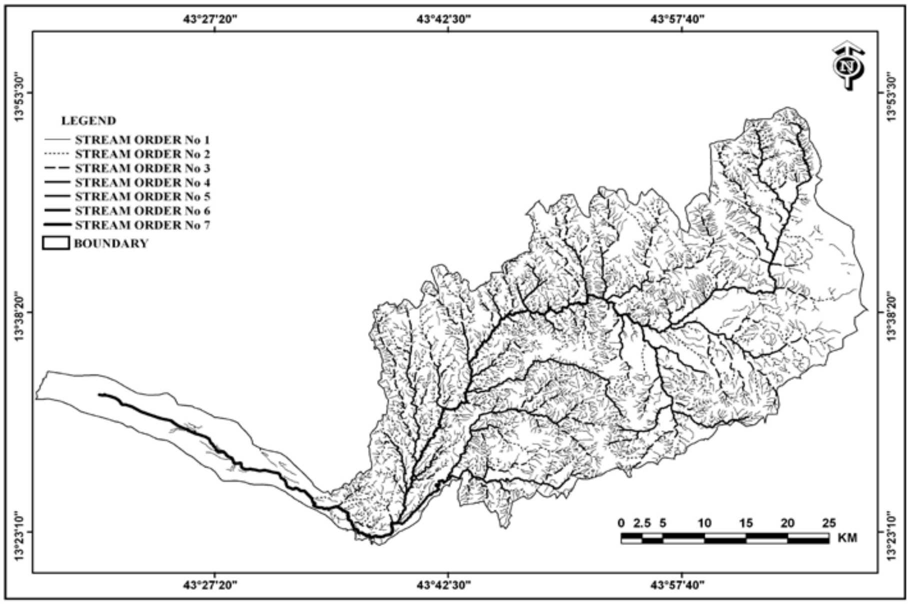

Fig. 4. Stream orders map of the Rasyan valley basin

2.3. *Climate*

The weather in the area is hot and rainy in summer whereas dry and temperate in winter, this weather is accomplished with variation temperature different parts of the area, in other words, temperature reaches 25° C at north and eastern parts of the area (Civil Aviation & Meteorology, 2004), while it rises 32° C in western part (TDA, 2003). Average of rainfall at the eastern part of study area is 600 mm whereas it is 800 mm in northern extent in contrast this average did not reach 50 mm in western extent (TDA, 2003).

3. Result and discussion

3.1. *Stream order (u)*

The stream orders of the Rasyan valley basin have been ranked according to the (Strahler, 1964) steam ordering system and the number of streams of each segment (Nu) of the order (u) (Fig. 4).

The total of stream orders in RVB are 4123 and these stream orders are distributed to 3288 in the first order, 646 in the second order 141 in the third order, 35 in the fourth orders, 9 in the fifth orders, 3 in sixth and 1 in the seventh order (Fig. 4). whereas difference in distributing of the stream orders of the sub-basins, *e.g.*, the less number of the stream orders in Wadi Aladboor sub-basin 33 is distributed to 24 orders in the first order, 6 orders in the second, 2 in the third and 1 in the fourth orders.

3.2. *Stream length*

The number of streams of various orders in the basin and sub-basins are counted and their lengths from mouth to drainage divide are measured.

The stream length has been computed based on the low proposed by (Horton, 1945). Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. The stream segments of various order show variation from general observation, this change may indicate flowing of streams from high elevation; lithological variation and moderation steep slopes.

Whereas the number and the length of the stream orders in the study area 3908.79 km distributed to the length of the first order 233.10 km, second order 742.74 km, third order 425.75 km, fourth order 196.24 km, fifth order 90.74 km, sixth order 75.74 km and the length of seventh order 46.34 km.

3.3. *Stream length ratio (RL)*

Stream length ratio (RL) may be defined as the ratio of the mean length of the one order to next lower order of

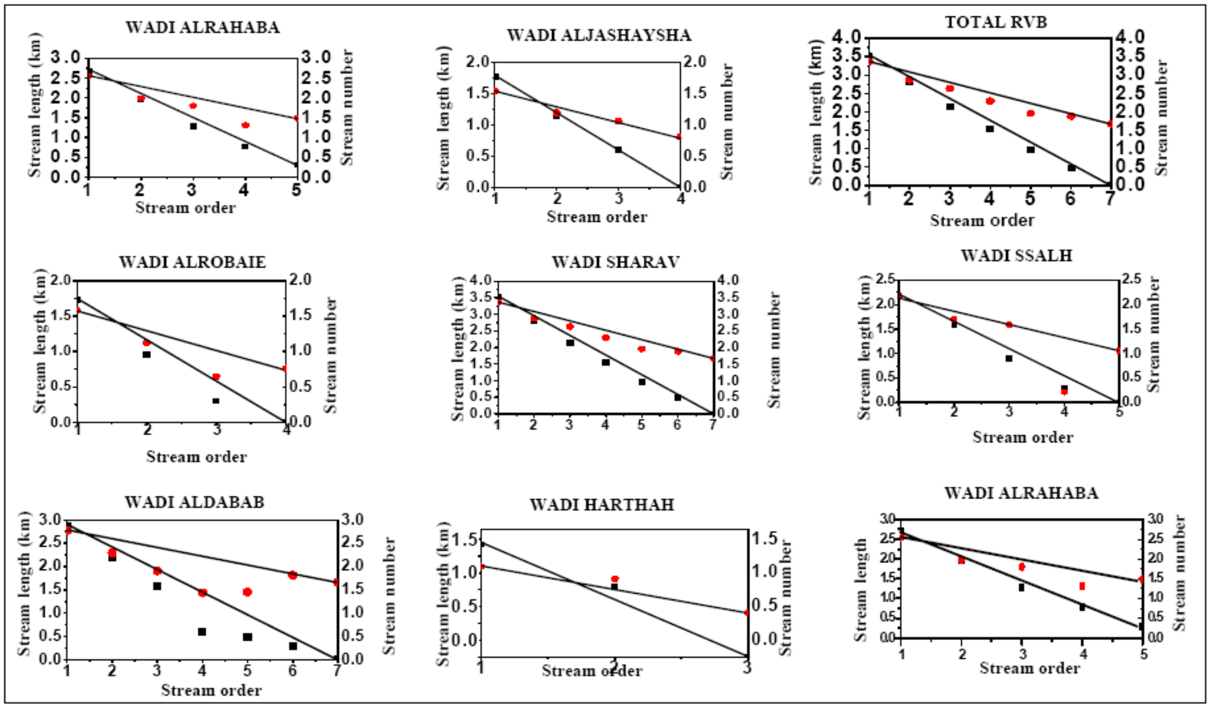

Fig. 5. Relationship between the stream order and stream length in RVB

stream segment (Horton, 1945) of stream length states than mean stream length segments of each of successive orders of a basin tends to approximate a direct geometric series with stream, length increasing towards lower order of streams. The RL between streams of different order in RVB, this variation due to changes in slope and topography:

RL = Lu/Lu-1

Where:

RL = Stream length ratio

Lu = Mean stream length order 'u'

Lu-1 = Mean stream length of segment of the next lower order

The ratio of average of the length of orders to their number was noticed that increasing the number of stream order, in the first order, to second stream orders are 3.14 km, second stream orders to third stream orders 1.74 km, third stream orders to fourth stream orders 2.17, fourth stream orders to fifth stream orders 2.16 km, fifth stream orders to sixth 1.2, sixth stream orders to seventh 1.64 km. The Fig. 5 shows the relationship between the stream order and stream length in Rasyan valley basin and same sub-basins in the study area.

3.4. *Basin length, width and perimeter*

Basin length has been given different meanings by different workers (Schumm, 1956), the basin length is the longest length of the basin and end being is mouth. The length of RVB is 196 km while the lengths of the all sub-basin between 5.99 km in Wadi Aladboor sub-basin and 26.8 km Wadi Alrahaba sub-basin respectively.

The measurement of the width is difficult because of difference the shape and boundary of the valley basin, so it is useful to take the average of this dimension (total 9.7 km) and for the basin contrast between (9.2 & 1.4) (Mahsoob, 2001).

Rasyan valley basin perimeter is 340 km while the sub-basin range between 330 km (Wadi Rasyan sub-basin) and 15.1 km (Wadi Aladboor sub-basin).

3.5. *Form factor (Ff)*

Form factor of a drainage basin is expressed as the ratio of average width of basin where axial length is the distance along the longest basin dimension parallel to the main drainage line, so the form factor is expressed as

$$Ff = A/Lp^2$$

Where:

Ff = Form factor

A = Area of the basin

Lp^2 = Square of basin length

Length of the basin is the longest dimension from mouth to the farthest point on the perimeter of the basin, and width is measured normal to the length.

3.6. *Elongation Ratio (Re)*

The elongation ratio (Re) is calculated by using the following formula.

$$Re = 2\ A/\ L$$

Where:

Re = Elongation Ratio

2 = Constant

A = Area of the basin

L = Maximum of the length ratio

The defined elongation ratio (Re) as the ratio between the diameters of the circle of the same area as the drainage basin and the maximum length of the basin, a circular basin is more efficient in the discharge of run-off than an elongated basin, the values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6 – 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). These values can be grouped into three categories namely:

(*i*) Circular (>0.9)

(*ii*) Oval (0.9 to 0.8)

(*iii*) Less elongated (<0.7).

In RVB the Re 0.17 and sub-basin between 0.1 and 0.54.

3.7. *Circularity ratio (Rc)*

The ratio of the circle having the same circumference as the perimeter of the basin circulatory ratio (Miller, 1953). It is also influenced by the length and frequency of stream, geological structures, land use and caver, climate, relief and slope of the basin expressed as

$$Rc = 4\ \pi\ A/\ P^2$$

Where :

Rc = Basin circularity

A = Area of the basin

P = Perimeter of the basin

The circulatory ratio of the area is around 0.02, this is evident that the area is far away from circular shape, but other sub-basins range between 0.0057 and 0.694, so they do not take circular form. The ratio of length to width in Rasyan valley basin is around 20.33, which equals five times the width and this ratio in Wadi Rasyan basin is the highest, because its linear extent from east to west .The other sub-basins have a ratio between 6.66 & 2.15.

3.8. *Drainage density*

Horton, 1932 has introduced drainage density into American hydrologic literature as an expression to indicate the closeness of spacing of channels. It is defined as the total length of stream of all orders per drainage area.

Langbein, 1947, recognized the significance of drainage density as a factor determining the time of travel by water and he also suggested a drainage density varying between 0.55 and 2.09 km / km^2 in humid region with an average density of 1.03 km / km^2. Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, surface roughness and run-off intensity index. Of these, only surface roughness has no significant correlation with drainage density. The amount and type of precipitation such as thundershowers, loses greater percentage of rainfall as run-of resulting in more surface drainage lines.

Amount of vegetation and rainfall absorption capacity of soils, which influences the rate of surface run-off, affects the drainage texture of an area. The semi-arid regions gave finer drainage density texture than humid

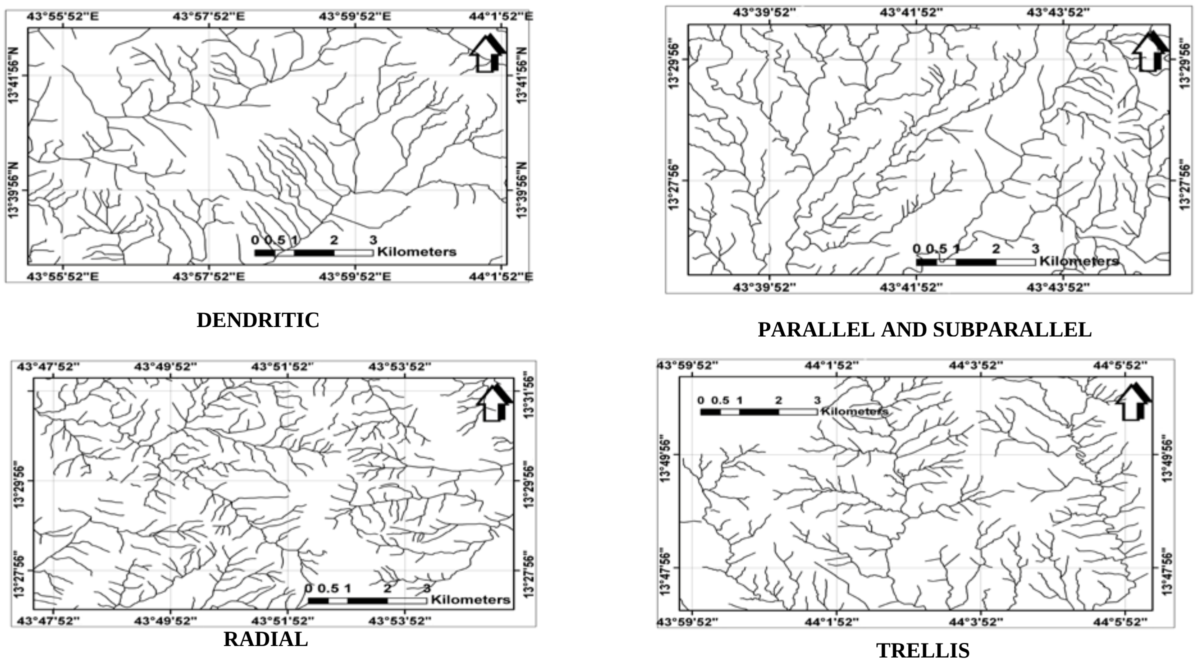

Fig. 6. Major drainage patterns in Rasyan valley basin

region. Low drainage density result in the areas of highly resistant or permeable subsoil material, dense vegetation and low relief (Nag and Chakraborty, 2003). High drainage density is the result of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to cores drainage texture while high drainage density leads to fine drainage texture.

The drainage density varies between 1.5 and 2.9 km/km^2 indicating low drainage density. In the present case, it is suggested that this low drainage density indicates the region has highly permeable subsoil and dense vegetation cover.

As shown from the values of drainage density, there are similarities between the sub-basins with slightly difference. This is referred to the similarities of different processes, which affected the drainage system in the study area. The types of the drainage in study area are depending on the (Fig. 4). There are four types of drainage patterns in Rasyan valley basin, (Type the dendritic, sub-dendritic radial trellis and type of drainage the parallel) (Fig. 6).

3.9. *Drainage texture*

Drainage texture (Rt) is one of the important concepts of geomorphology which means that the relation between spacing of drainage lines. Drainage lines are numerous over impermeable areas than permeable areas. According to (Horton, 1945), Rt is the total number of stream segments of all order per perimeter of than area. He recognized infiltration capacity as the single important factor which influences Rt and considered drainage texture which includes drainage density and stream frequency (Smith, 1935) has classified drainage density into five different textures. The drainage density less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. In the present study, the drainage density is of very coarse to coarse drainage texture.

$$T = Dd \times Fs$$

Where

T = Drainage texture

Dd = Drainage density

Fs = Stream frequency

Based on the values of drainage texture it is classified as

For 4.0 and below – coarse

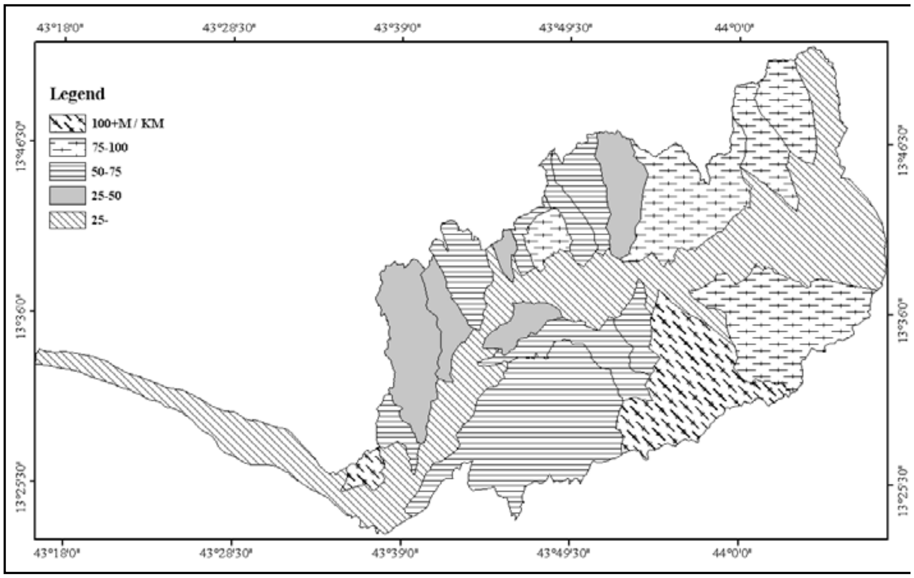

Fig. 7. Cassification relief ratio of Rasyan valley basin

From 4.0 to 10.0 – intermediate

Above 10.0 – fine

The relief ratio was classified to five levels (Fig. 7). (0.100 + m/km, 0.75-0.100, 0.50-0.75, 0.25-0.50 and 0.25-). There are similarities between the relief ratio and digital elevation model; however, little difference in high land of Wadi sub-basin resulting from length of Wadi Rasyan sub-basin from east to west which this classification of relief ratio depends upon, the hypsometric curve (Strahler, 1952a.), in Rasyan valley is 79% (Fig. 8). This result does not mean that Rasyan basin reaches to that stage of development of the geomorphological nuts, because of the area lies between line contours 600 meter and 1600 meter above level of the sea.

In addition, it mostly takes the shape of plateaus and it covers the area of 1511.16 km^2. The coarse ratio in the study area is 6.23, with a little difference in the sub-basin. Whereas in Wadi Aladboor sub-basin 4.06, Wadi Alrahaba sub-basin 4.61 and Wadi Alramada sub-basin 4.10 and between is 0.68 & 3.46 in the other sub-basin respectively. The number of the coarse ratio is high in the study area, which shows the activity of erosion processing (capacity for carry, chisel and sediment) in sub-basin and indicates the relief in the Rasyan valley.

3.10. *Bifurcation ratio (Rb)*

The tern "Bifurcation ratio" may be defined as the ratio of the number of the stream segments of given order to the number segment of the next higher order (Schumm, 1956; Horton, 1945), considered the bifurcation ratio as an index of relief and dissection. (Strahler, 1957) demonstrated that bifurcation ratio shown a small range of variation for different regions or different environment except where the powerful geological control dominates. The bifurcation ratio is not same form one order to its next order.

These irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler, 1964). The lower values of bifurcation ratio are characteristics of the RVB which have suffered less structural disturbances and the drainage patterns has not been distorted because of present RVB, the higher values of bifurcation ratio indicates strong structural control on the drainage pattern while the lower values indicative of RVB that are not affected by structural disturbances.

The bifurcation ratio in Rasyan valley is 3.931 and bifurcation weighted ratio in Rasyan valley is 4.954 and these indicate that the risks of the floods decrease at the high stream orders and increase at down stream orders. And also average of folding in Rasyan valley reaches 1.8 km for each km, Wadi Al Haymah is 1.25, Wadi Hartha is 1.2 and this proved that the real length of these rivers is more than the ideal lengths.

These rivers are not at mature stages but indicate that the influence of the river valleys by the geological structure and relief which make the valleys turn around the mountains, hills which leads to its length.

3.11. *Relief ratio*

The elevation difference between the highest and lowest points on the valley floor of the RVB is known as the total relief of that RVB. The relief ratio of maximum relief to horizontal distance along the longest dimension of the basin paralled to the principal drainage line is termed as relief ratio (Schumm, 1956). There is direct relationship between the relief and channel gradient. There is also a correlation between geomorphological characteristics and the relief ratio of a drainage basin. The relief ratio normally increases with decreasing drainage area and size of the RVB of given drainage basin. According (Schumm, 1956) the relief ratio as:

$$Rh = H/Lb$$

Where,

Rh = Relief ratio

H = Total relief (Relative relief of basin in kilometers)

Lb = Basin length

The values of relief ratio are given in Fig. 7 and range form 0.015 to 0.109. It is noticed that the high values of relief ratio indicate steep slope and high relief 3015 m, while the lower values may indicate the presence of basement rocks that are exposed in the form of small series and mounds with lower degree of slope.

3.12. *Gradient ratio (RG)*

The Gradient ratio is an indication of channel slope. It is calculated by the following formula gradient ratio:

$$RG = a-b / L$$

Where

RG = Gradient ratio

a = Highest elevation point from the source of stream

b = Lowest elevation point at the mouth of stream

L = Length of the main stream

Gradient value of the RVB is 0.015 and different in sub-basin between 0.11 (Wadi Aldabab sub-basin) and 0.14 (Wadi Rasyan sub-basin).

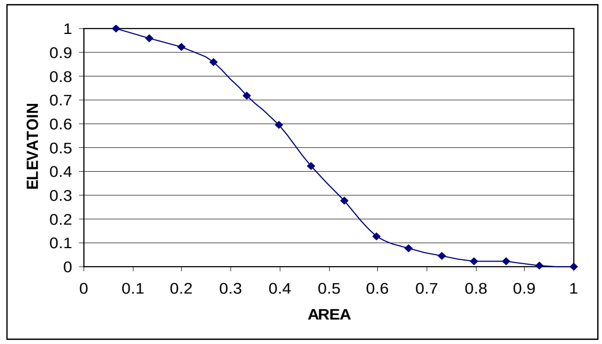

Fig. 8. Hypsometric curve of geomorphological revolution in RVB

4. Conclusion

Morphometric analysis of Rasyan valley basin with shape, relief and the characteristics of river draining network has been studied and classified. The rectangular shape of the basin, which is extending from the east to west, reduces the risks of floods. All the other sub-basins take the rectangular shape, in spite of the difference of the climate and topography, which can give evidence that the geology of area has an effect on the shapes of the individual sub-basins in the study area.

The high slopes (especially) dense in the northern and south eastern parts and getting less in the direction of the west are part of the study area. The increase of the vertical erosion development of the basin is due to geomorphological features of the area.

Lengths of the stream orders in the sub-basins are increased due to different geomorphological changes with geological and structural formation. (The streams turn between the mountains, hill, plateaus) and not the late river revolution.

The increase in the river drainage network in the first stream orders of the basin and the short distances of these stream orders help the increase of water denudation and erosion in the basin. The type of dendritic river drainage represents the most parts of the basin because of the rocky volcanic formations, whereas the dominance of the rectangular type of drainage represents some parts because of the lithological younger intrusions and geomorphological changes in the study area.

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