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RESEARCH ARTICLE

GIS – BASED MORPHOMETRIC ANALYSISOF KUNAR RIVER BASIN IN AFGHANISTAN

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Abstract

A quantitative evaluation of river drainage systems is necessary aspect of a watershed.The morphometricanalysis of the river basin and channel network plays animportant role in comprehension of the geo-hydrological nature of drainage basins. It expresses the prevailing climate, geological setting, geomorphology and structural behavior of the catchment area. In this study, the Digital Elevation Model (DEM) of Kunar river basin is used for delineation of the river basin and processed for morphometric analysis using GIS. The linear, areal, relief and gradient aspects of the river basin are determined for a detailed morphometric analysis of Kunar riverbasin.

Introduction:-

Morphometric analysis is evaluation of form characteristics of the earth surface and landforms and used for river basin analysis.Morphometric analysis is imperative to any hydrological study and it is used as reconnaissance tool to give information regarding particular characteristics of an area. Co-relating of stream networks behavior can be indicate as morphometric analysis.The maincharacteristics of morphometric analysis are measurement of linear features, gradient of channel network and contribution of ground slope or measurement of linear, areal and relief aspects of sub-basins of a watershed[1], [18].

Morphometric analysis of river basin was introduced by Horton (1945)and he have given law of stream length whichindicates that there is a geometric relationship between number of stream segment and successive stream order. Then this technique is modified by Strahler (1952, 1957, 1958, and 1964), Schumm (1956), Morisawa (1957, 1958), Scheidegger (1965), Shreve (1967), Gregory (1966, 1968), Gregory and Walling (1973) [18].The morphometric analysis is useful for reservoir planning [2] and basin drainage characteristics [3, 4, 6]. Rafiq Ahmad Hajam1et al (2013) applied morphometric analysis for geo-hydrological studies using geo-spatial technology [5].

Morphometric analysis is used in study of geomorphology, lithological natureand surface-water hydrology. The morphometric characteristics of basin can be co-related to the sediment yield coming from the basin. Similarly flood characteristics, evaluation of basin morphology and the aspect of morphometry can be linked with flow characteristics and fluvial process.

The prediction of the stream discharge of a basin when thecharacteristics such as elevation, main channel gradient

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The Geographic Information System (GIS) with satellite images such as Digital Elevation Model (DEM) and Shuttle Radar Topography Mission (SRTM) is a convenient tool for morphometric analysis. In this paper, DEM was obtained from United States Geological Survey (USGS) and using GIS the Kunar riverbasin is delineated and flow fill, flow direction, flow accumulation, stream network map, slope map for the basin, contour map, hill shad map and profiles for the watershed are obtained.

Kunar river basin is an important source of surface water in Afghanistan. In topographic profile of Afghanistan,the central parts of the country are the peaks and mountainous and the river streams flow to lowlands, deserts and neighboring countries. Parts of the country located at elevation above 4200m receive heavy snow and regions having 1200m receiving combination of snow and rain whichsupply most parts of the country with water during the spring and early summer months.

Afghanistan is a mountainous country and agriculture is along the river streams in bed of valleys. Themaximum precipitation in the country occurs during the winter and spring seasons, water provided by snow melts and glaciers from mountains for most perennial streams. The major problem caused by this water supply has always been the heavy and often destructive flows that occur in thespringtime. Traditional and occasionally modern water control structures are often destroyed or rendered inoperable during the high spring flows [19].

Study Area:-

There are four River basins in Afghanistan which are Amu River Basin, Helmand River Basin, Kabul River Basin and Harirud and Murghab River Basin. Kunar river basin is a part of Kabul River Basin. Kabul river basin originates 80 Km west of capital Kabul from north-central portion of the Wardak province and flows east to Jalez , adding water of SanglaKhvalley of Hindu Kush Mountains and after 700 km it empties in Indus River near Attock, Khyber Pakhtunkhwa. The Kabul River and its tributaries drain about 52000 Km^2or approximately 8 percent of total area of Afghanistan. Combined flow of Kabul River with major tributaries averagely is about 23100 million cubic meter or about 40 percent of total surface water of the country. Kabul river basin is a main river basin in eastern Afghanistan and separates from Helmand watershed at Unai Pass and it flows through cities of Kabul and Jalalabad before flowing into Khyber Pakhtunkhwa about 25 Km north of Durand line crossing at Torkham. The major tributaries of Kabul River are the Logar, Panjshir, Kunar, Alingar, Bara and Swat rivers[19].The Laghman and Kunar are the easternmost tributaries of the Kabul River fed by snow melt and glacier runoff from the mountains of the Hindu Kush., The Lowgar, Ghorband, and Panjsher are western and northern tributaries of the Kabul River, are more affected by seasonal and annual fluctuations in precipitation. These streams run high during the spring and early summer months but drop quickly once the snow melt is finished [19].

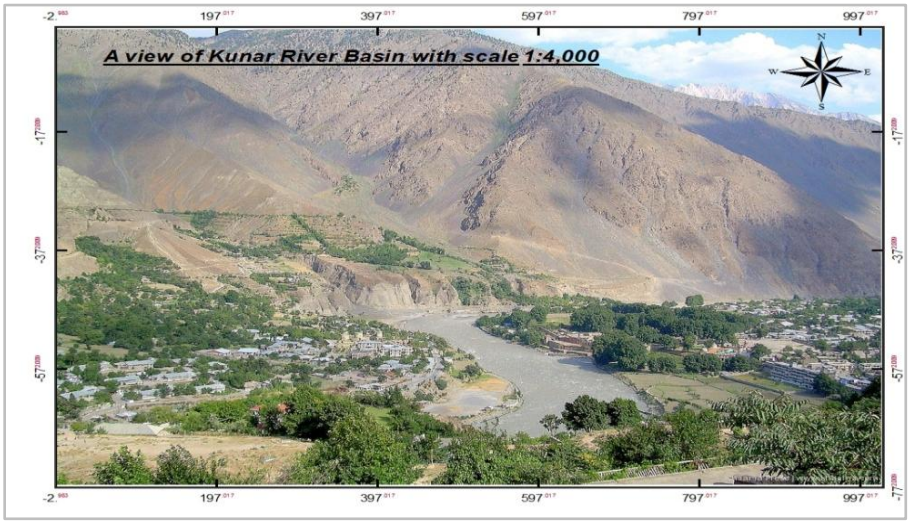

Figure 1:-A view of Kunar river basinat Asmar

Kunar River is a main tributary of Kabul river basin which located in eastern Afghanistan and northern Khyber Pakhtunkhwa. It originates from glaciated Hindu Kush Mountains of Chitral, Khyber Pakhtunkhwa and a little downstream it is known as Mastuj River which meets Lukhto/Yarkhunriver at north of Chitral and named as Chitral river. Kunar River is fed from melting of glaciers and snows of Hindu Kush Mountains.When it flows south and enter Nari district of Kunar Province Afghanistan, it is called Kunar River. Kunar River has two main tributaries which are Bashgal also called Landiasind and Pech River.Pech Rivermeets the Kunar River in Asadabad historically Chaga Saria and Landiasind fed with numerous streams in Bargi Matal and Kamdesh districts Nuristan and join the

Kunar River at Nari district Kunar province. Finally Kunar River joinsthe Kabul River just east of the Jalalabad city[www.wekipedia.com], [19], and [20]. A view of Kunar River and its basin is shown in figure1.

Land Cover and Vegetation:-

Kunar river basin is dominated by natural forests about 38 percent which is decreasing, range-lands 24 percent, permanent snow 18 percent and bare soil 11 percent. Irrigation land is very less and it seems in narrow strips on valley floors and represents approximately 3.2 percent of the basin area. Rain fed cultivation is also practiced 0.5 percent. The land cover classification of Kunar river basinis mentioned in table 1 [20].

Table 1:-Land cover classification of Kunar river basin.

Land Cover	Area (Km^2)	Percentage Watershed
Degenerate Forest/High Shrubs	161.8	1.39
Irrigated: Intensively Cultivated (1 Crop/Year)	118.6	1.02
Irrigated: Intensively Cultivated (2 Crops/year)	59.0	0.51
Irrigated: Intermittently Cultivated	197.1	1.69
Marshland Permanently inundated	48.3	0.41
Natural Forest (closed cover)	4436.8	38.04
Natural Forest (open cover)	482.5	4.14
Permanent Snow	2096.1	17.97
Rain fed Crops (sloping areas)	59.0	0.51
Rangeland (grassland/forbs/low shrubs)	2775.2	23.79
Rock Outcrop / Bare Soil	1228.0	10.53
Water Bodies	1.2	0.01
Total	**11663.6**	**100.00**

Precipitation and climate:-

Kunar river basin has three different types of climate which are hot-summer Mediterranean, hot semi-arid and warm humid continental. Precipitation mostly occurs in winter with relatively little rain in summer. The average annual temperature is19.4^{o}C. Average yearly precipitation in Asadabad center of Kunar province is 532 mm, the least amount of rainfall happen in June and average in this month is 11 mm. In March the precipitation reach its peak with an average 111mm. The highest temperature around 31.2^{o}C is inJuly, andaverage 7^{o}C.January is the coldest month of the year. The variation of precipitation between driest and wettest month is 100mm. The variation of annual temperature is around 24.2^{o}C. Kunar climate and average monthly precipitation is given in table 2[Climate-data.org], [19].

Table 2:-Average monthly precipitation and average monthly temperature for Asababad Kunar

Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Av. precipitation (mm)	44	67	111	104	45	11	28	30	17	17	18	40
Av. Temperature (^{0}C)	7.0	9.3	13.8	18.6	24.2	30.2	31.2	29.9	26.6	20.2	13.5	8.4

Methodology:-

Morphometric analysis of a river basin requires delineation of all existing streams and river reaches. There are several methods of river basin delineation which can be done manually or automatically. Kunar river basin is delineated as shown in figure2.

For morphometric analysis of Kunar river basin, the Digital Elevation Model (DEM) was taken from United States Geological Survey (USGS), and ArcGIS is used for further processing. The DEM is projected to equate more precisely the location on map with their true location on the earth. Fill of the DEM was also done for proper delineation of basin and streams. Then maps for flow direction, flow accumulation, watershed, river streams, contours, slope, profile of basin, hill-shade etc. were generated.

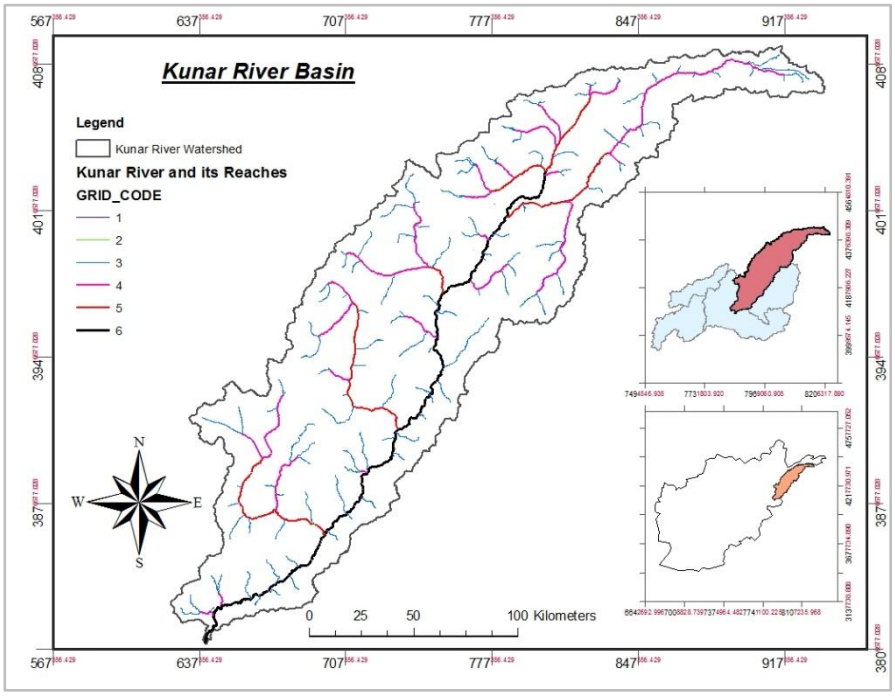

Figure 2:-Kunar river basin with main river network.

For detailed analysis the whole Kunar river basin.It is divided into six sub-basinsshown in figure 4. The morphometric parameters are determined for each sub-basin and the results are also collected for whole Kunar river basin. The morphometric analysis of Kunar river basin is performed with obtaining of linear parameters, areal parameters and relief parameters.

Linear morphometric parameters which are obtained are stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, and basin length.Area morphometric parameters discussed here are drainage area, drainage density, drainage or stream frequency, drainage texture, basin shape, elongation ratio, circular ratio and form factor.The relief aspects which are obtained are basin relief, channel gradient, relief ratio and longitudinal profile of the river basin. The procedure chart is shown in figure 3.

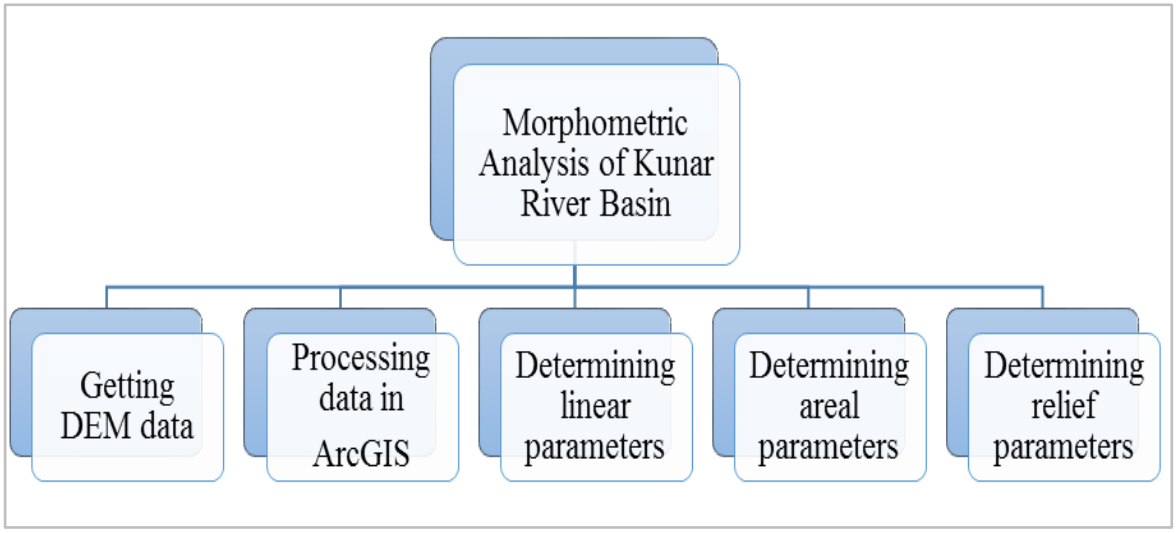

Figure 3:-Procedure for obtaining morphometric parameters of Kunar River basin

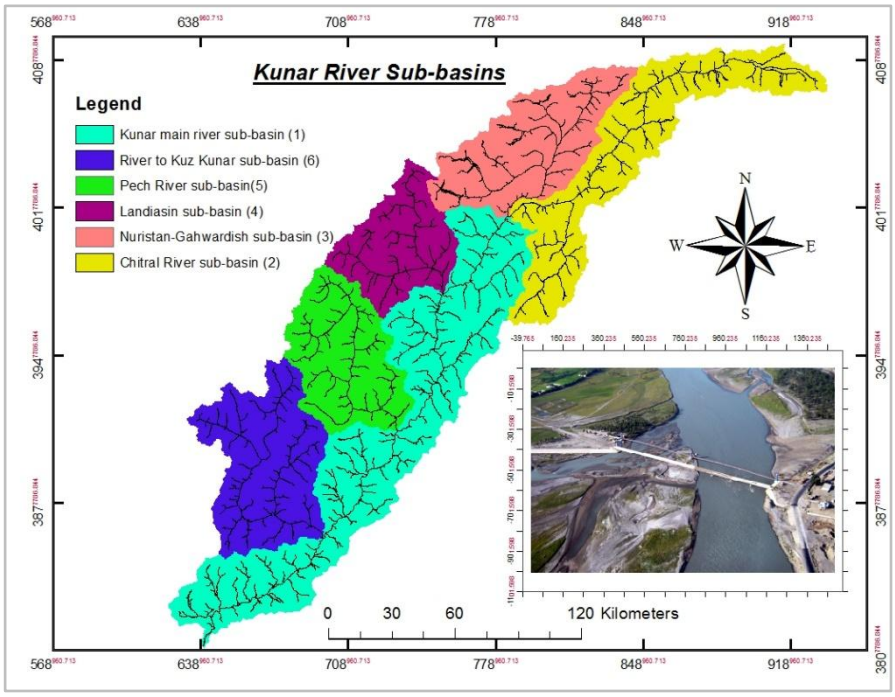

Figure 4:- Sub-basins of Kunar River basin

Results and Discussion:-

Usually, morphometric analysis of drainage system is prerequisite to any hydrological study. The determination of stream network behavior and their interrelation with each other hasa great importance in many water resources studies.Also, morphometric analysis shows relation between river capacity to adjust incoming runoff and sediment load.

The high values of drainage density, stream frequency and drainage intensity implies that surface runoff is not quickly removed from basin [1]. Morphometric analysis was carried out for Kunar river basin and results are given in following tables.

Table 3:-Morphometric parameters of Kunar river basin and its sub-basins

No	Morphometric Parameters	Units	Kunar River basin	Sub–1	Sub–2	Sub–3	Sub–4	Sub–5	Sub–6
1	2	3	4	5	6	7	8	9	10
1	Catchment Area (A)	Km^2	25951.9	8153.4	4724.3	3583.6	2465.0	3136.6	3880.8
2	Perimeter of the Catchment (P)	Km	1348.17	846.84	647.79	343.42	283.79	301.91	384.21
3	Stream Highest Order		6	5	5	6	5	5	5
4	Cumulative Stream Num (Nu)		3330	1020	644	502	287	487	390
5	Maximum Length of basin	Km	426.493	264.65	222.13	117.51	75.757	76.967	103.23
6	Maximum width of Catchment	Km	60.850	30.808	21.268	30.495	32.538	40.752	37.592
7	Cumulative Stream length (Lu)	Km	7668.812	969.34	1238.2	1658.6	969.34	1238.2	1595.4
8	Cumulative Stream segment		5545	1718	774	822	469	622	777
9	Mean stream length Ratio		0.626	0.436	0.367	0.608	0.828	0.386	0.427
10	Length of over land flow (Lo)		1.692	4.206	1.908	1.080	1.271	1.267	1.216
11	Main Stream Length	Km	520.371	204.07	316.31	103.32	75.117	128.14	134.09
12	Drainage density (Dd)	Km^{-1}	0.296	0.119	0.262	0.463	0.393	0.395	0.411
13	Constant of channel maint (C)		7.793	7.994	7.336	7.139	8.589	6.441	9.951
14	Stream frequency (Fs)	Km^{-2}	7.793	0.125	0.136	0.140	0.116	0.155	0.101
15	Mean Bifurcation ratio (Rb)		4.948	5.418	5.098	3.478	4.145	4.613	4.285

16	TextureRatio (Tr)		0.412	0.241	0.199	0.244	0.202	0.323	0.203
17	Form factor (Rf)		0.1427	0.117	0.0957	0.2595	0.4295	0.5295	0.3642
18	Shape factor (Rs)		7.009	8.590	10.444	3.854	2.328	1.889	2.746
19	Unit shape factor (Ru)		2.647	2.931	3.232	1.963	1.526	1.374	1.657
20	Circularity ratio (Rc)		0.17942	0.1429	0.1415	0.3818	0.3846	0.4324	0.330
21	Elongation ratio (Re)		0.4262	0.385	0.349	0.5748	0.7395	0.821	0.681
22	Total Catchment relief (H)	Km	7.157	7.155	4.765	5.785	6.039	5.194	4.932
23	Ruggedness Number (Rn)		2.1149	0.8506	1.2488	2.6774	2.3748	2.0503	2.0276
24	Finesse Ratio (Ri)		0.3164	0.3125	0.3429	0.3422	0.2669	0.2549	0.2687
25	Wandering ratio (Rw)		1.22012	0.7711	1.4239	0.8792	0.9916	1.6648	1.2989
26	Infiltration Number (If)		2.303	0.015	0.036	0.065	0.046	0.062	0.041

Stream length:-

Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. The stream of relatively smaller length is characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradient. In Kuanr river basin, the total length of stream segments is maximum in first order, stream length decreases as stream order increases. Itis the quantification of hydrological characteristics of bedrock and the drainage extent. When bedrockis of permeable character then only small number of relatively longer streams are formed in a well-drained basin area. On the other hand, when the bed rock is less permeable then large number of smaller length of streams in the basin are produced [1].

The order-wise stream lengths in Kunar river basin arementioned intable 4. The stream order is first step in morphometric analysis of river basin and it gives the classification of location of reach within river drainage basin. It is identified that cumulative stream length is maximum in first order streams and decreases as the stream order increase. The highest stream order 6thin Kunar River basin is 37.182 Km long.

Table 4:- Stream length of Kunar River basin with its sub-basins

No	Sub-basin	Stream length (Km) according to stream orders					
		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ
1	Kunar Main River Sub-basin(1)	487.656	233.394	140.838	87.539	19.913	-
2	Chitral River Sub-basin(2)	656.563	295.039	139.122	58.686	88.694	-
3	Gawhardish River Sub-basin(3)	857.927	392.684	156.496	133.749	80.495	37.182
4	Landaisind River Sub-basin(4)	487.656	233.394	140.838	87.539	19.913	-
5	Pech River Sub-basin(5)	656.563	295.039	139.122	58.686	88.694	-
6	Kuz Kunar Sub-basin(6)	880.997	340.495	190.907	94.056	88.933	-
7	Kunar River basin	4027.364	1790.044	907.324	520.255	386.642	37.182

Mean Stream Length:-

Mean stream length disclose the size of component of drainage network and its contributing surface. It is directly proportional to the size and topography of drainage basin. It has been computed by dividing the total stream length of order ‘u’ by the number of stream segments in that order. It is noted that mean stream length value of any stream order is greater than that of the lower order and less than that of its next higher order in the basin. Table 5 gives the mean stream length of Kunar river basin which varies from 2.824 Km to 88.933 Km in length.

Table 5:-Mean stream length of Kunar River basin with sub-basin orderly

No	Sub-basin	Mean stream length (Km) according to stream orders					
		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ
1	Kunar Main River Sub-basin(1)	0.609	1.365	3.521	12.506	19.913	-
2	Chitral River Sub-basin(2)	1.287	2.810	5.565	19.562	88.694	
3	Gawhardish River Sub-basin(3)	2.194	4.909	7.825	16.719	40.248	37.182
4	Landaisind River Sub-basin(4)	2.158	4.966	12.803	43.769	19.913	-
5	Pech River Sub-basin(5)	1.646	4.339	8.695	19.562	88.694	-
6	Kuz Kunar Sub-basin(6)	2.824	5.582	14.685	31.352	88.933	-
7	Kunar River basin	1.526	3.365	7.259	20.010	55.235	37.182

Stream Length Ratio:-

Horton's law of stream length states that mean stream length of each of the consecutive segment of a basin tends to approximate a direct geometric series with stream increasing towards higher order. The stream length ratio has important relation with surface flow, discharge and erosion stage of the basin [1]. The stream length ratio for Kunar river basin is shown in table 6. The stream length ratio between the streams of different orders of the Kunar river basin shows a change in each sub-basin. This change might be attributed to variation in slope and topography that indicates the late youth stage of geomorphic development in the streams of the basin.

Table 6:-Stream length Ratio of Kunar River basin with its sub-basins

No	Sub-basin	Stream length ratio according to stream orders				
		Ⅰ-Ⅱ	Ⅱ-Ⅲ	Ⅲ-Ⅳ	Ⅳ-Ⅴ	Ⅴ-Ⅵ
1	Kunar Main River Sub-basin(1)	0.45	0.39	0.28	0.63	-
2	Chitral River Sub-basin(2)	0.46	0.51	0.28	0.22	-
3	Gawhardish River Sub-basin(3)	0.45	0.63	0.47	0.42	1.08
4	Landaisind River Sub-basin(4)	0.43	0.39	0.29	2.20	-
5	Pech River Sub-basin(5)	0.38	0.50	0.44	0.22	-
6	Kuz Kunar Sub-basin(6)	0.51	0.38	0.47	0.35	-
7	Kunar River basin	0.45	0.46	0.363	0.362	1.49

Bifurcation Ratio:-

The bifurcation ratio as an index of relief and dissection(Horton, 1945). According to Strahler (1957), bifurcation ratio exhibit subtle fluctuation for different region with varied environment except where powerful geological control dominates. According Schumm (1956) had defined bifurcation ratio as the ratio of number of stream segment of given order to the number of segment in the next order, it is dimensionless property and indicates the degree of integration prevailing between streams of various orders in drainage basin.Strahler told that geological structures do not affect drainage pattern for bifurcation ratio in between 3.0 to 5.0. When bifurcation ratio is low, there will be high possibilities of flooding as water will tend to accumulate rather than spreading out. The human intervention plays important role to reduce bifurcation ratio which is risk of flooding within the basin [1]. The bifurcation ratios ofKunar river basin are given in table 7. The higher values of bifurcation ratio indicate a strong structural control in the drainage pattern whereas the lower values indicate that the sub-basins are less affected by structural disturbance [4].

Table 7:-Bifurcation ratio of Kunar River basin with its sub-basins

No	Sub-basin	Bifurcation ratio according to stream orders				
		Ⅰ-Ⅱ	Ⅱ-Ⅲ	Ⅲ-Ⅳ	Ⅳ-Ⅴ	Ⅴ-Ⅵ
1	Kunar Main River Sub-basin(1)	4.684	4.275	5.714	7	-
2	Chitral River Sub-basin(2)	4.857	4.200	8.333	3	-
3	Gawhardish River Sub-basin(3)	4.888	4.00	2.500	4.00	2.00
4	Landaisind River Sub-basin(4)	4.809	4.273	5.500	2.00	-
5	Pech River Sub-basin(5)	5.868	4.250	5.333	3.00	-
6	Kuz Kunar Sub-basin(6)	5.115	4.692	4.333	3.00	-
7	Kunar River basin	4.961	4.256	4.808	3.714	7.00

Relief Ratio:-

According to Schumm (1956), the maximum relief to the horizontal distance along the largest dimension of the basin parallel to the principal drainage line is termed as relief ratio. It computes overall steepness of the drainage basin. Relief ratio is an indication of the intensity of erosional process operating on slope of the basin. Relief ratio is inversely proportional to the drainage area and the size of given drainage [1]. The relief ratio normally increases with decreasing drainage area and size of a given drainage basin (Gottschalk 1964). Relief ratio for Kunar river basin is calculated 0.0168. Relief ratios of each sub-watershed of Kunar river basin areindicated in the table 8.

Table 8:-Relief ratio of Kunar River basin with its sub-basins

No	Sub-basin	Total relief (Km)	Maximum length (Km)	Relative Relief (Rr)	Relief ratio
1	Kunar Main River Sub-basin(1)	7.155	264.650	0.0084	0.027036
2	Chitral River Sub-basin(2)	4.765	222.134	0.0074	0.021451
3	Gawhardish River Sub-basin(3)	5.785	117.514	0.0168	0.049228
4	Landaisind River Sub-basin(4)	6.039	75.757	0.0213	0.079716
5	Pech River Sub-basin(5)	5.194	76.967	0.0172	0.067484
6	Kuz Kunar Sub-basin(6)	4.932	103.233	0.0128	0.047776
7	Kunar River basin	7.157	426.493	0.00531	0.016781

Drainage Density:-

Drainage density is a measure of the total stream length in a given basin to the total area of the basin (Strahler 1964). It relates to the various aspect of landscape dissection such as valley density channel head source, climate and vegetation, soil and rock properties, relief and landscape evolution processes.

The drainage density is directly proportional to basin relief(Strahler, 1964). The dissected drainage basin with a relatively rapid hydrological response to rainfall events, while low drainage density demonstrates poorly drained basin with a slow hydrological response [1],[4]. The drainage density of Kunar river basin is 0.295 Km/Km^2whichindicates that basin area has an impermeable subsurface material with intermediate drainage and high to moderate relief. Drainage density of Kunar river basin is shown in figure 5.

Slope of the River Basin:-

Slope analysis is an important parameter in geomorphological studies for watershed development and it is important for morphometric analysis. The slope elementsare controlled by the climate-morph-o-genic processes in areas having rock of varying resistance [1].

The degree of slope in Kunar river basinis found to vary from zero percent to 79.65 percent as it is shown in figure 6. Higher slope degree results in rapid runoff and increased erosion rate (potential soil loss) with less ground water recharge potential. Higher slope is identified in north-west part of the Kunar river basin.

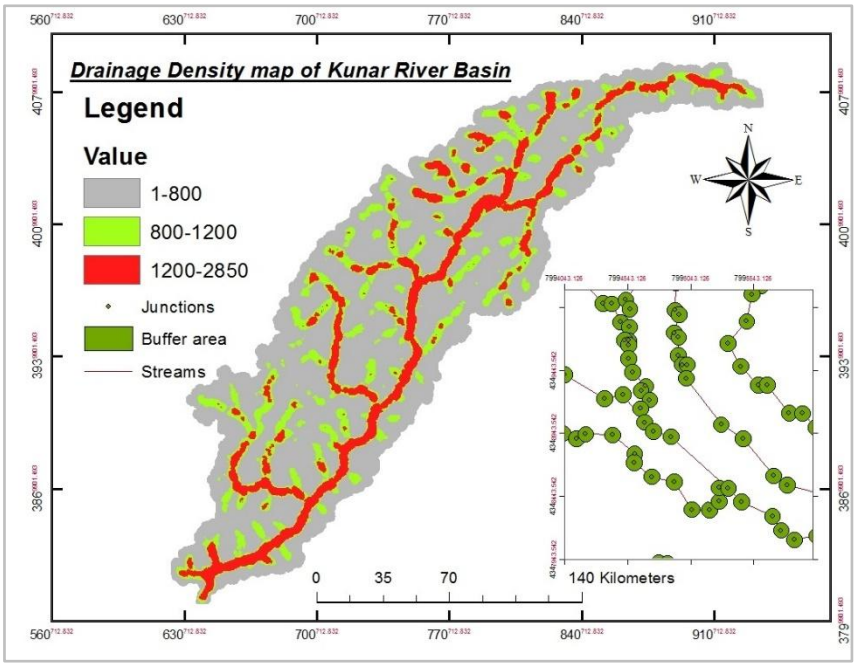

Figure 5:-Drainage density map of Kunar river basin

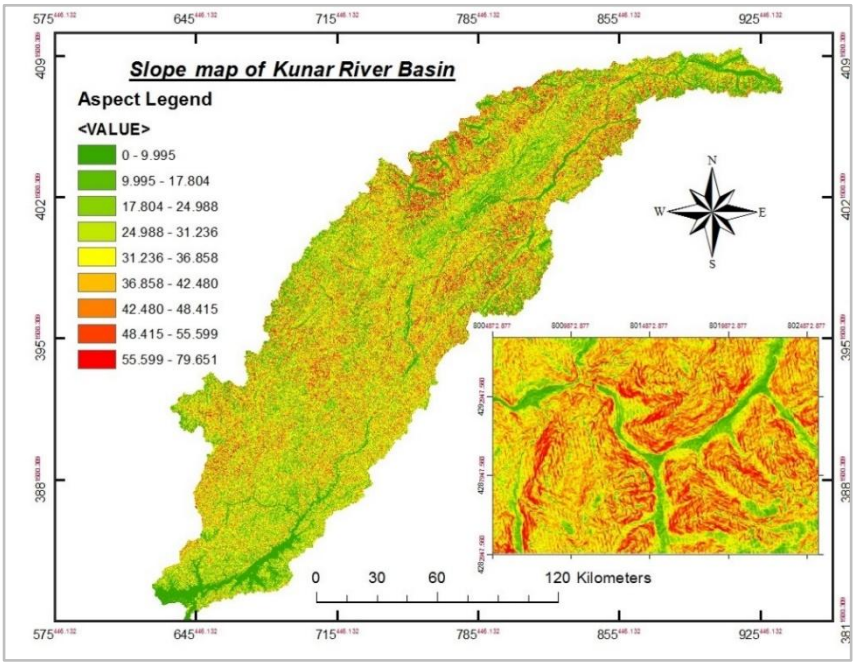

Figure 6:-Slope Map of Kunar River Basin

Longitudinal Profile:-

Longitudinal profile is geometrical property of catchment streams which can provide information regarding underlying materials, geologic process and geomorphic history of the basin. (Hack 1960) Longitudinal profile of stream channel is showed graphically as altitude (ordinate) as function of horizontal distance (abscissa).This change points represents the structural disturbance and the lithology control. All the major thrust and the transverse fault/ lineament are reflected as slope difference along the profile[18]. Longitudinal profiles of Kunar river basin along center line of main stream and centerline of basin is given as in figures 7.

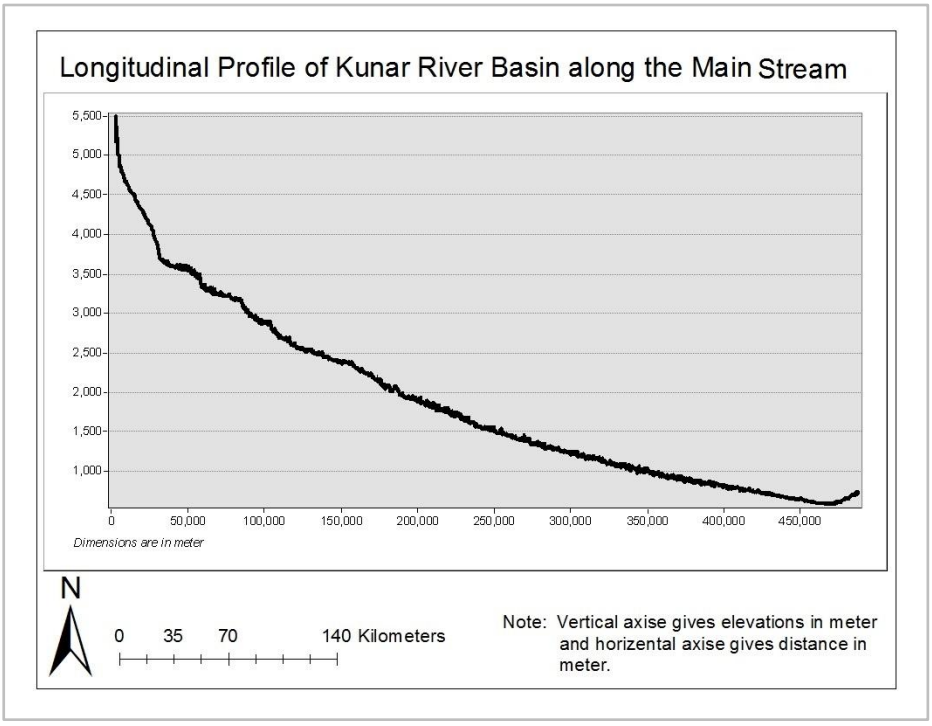

Figure 7:- Kunar river basin longitudinal profile along centerline of river

Conclusions:-

1. Morphometric analysis of drainage basin is important asthis provides information about catchment development on priority basis and areas vulnerable for land degradation.It can be used to optimize drainage basin management techniques that gives quantitative information on landform. Quantitative evaluation of morphometric parameters is essential tool in river basin analysis in term of soil and water conservation and natural resource management.
2. GIS techniques and remote sensing data is very effective tool in drainage delineation. The application of GIS in conjunction with old data sets brings a bright picture enabling researchers to get concrete information about basin characteristics.
3. Kunar river basin is a 6^{th} order basin and it is mainly dominated by low order streams and if total number of streams be consider 79.38 percent is first order streams.The presence of the maximum number of the first order segments shows that the basin is subjected to erosion and also, some areas of the basin are characterized by variations in lithology and topography. The deviation of the mean stream length values from 1.53 to 37.18 clearly indicates the change in topographic elevation and slope of the Kunarriver basin.
4. The bifurcation ratio of Kunar river basin is 4.95 that indicates basin is systematically branched and dominated with 1^{st}, 2^{nd} and 3^{rd} order streamsand basin is underlined by uniform materials, and streams are usually branched systematically. Bifurcation ratio of Chitral and Main Kunar river sub-basins is 5.42 and 5.10 respectively which indicates non-uniform materials and non-systematically branched streams but other sub-basins havebifurcation ratios less than 5.
5. The length of overland flow in Kunar river basin is 1.692 and it is more than 0.3, it indicates that the Kunar river basin has longer flow paths associated with more infiltration and reduced runoff.
6. The drainage density of Kunar river basin is less than 2, hence it falls under very coarse texture category.
7. The higher value of stream frequency as 7.793 Km^{-2} is observed in Kunar river basinand it indicates the low conducting sub-surface material, sparse vegetation and high relief.
8. The elongation ratio of Kunar river basin is 0.43 which indicates that Kunar river basin is an elongated basin. TheSub-basin of Main Kuanr River, Chitral, Nuristan-Gahwardish, and River to Kuz-Kunar are also elongated basinswhile Landiasind sub-basin having elongation ratio of 0.74 which isless elongated, Pechriver sub-basin has elongation ratio of 0.82 indicating an oval basin.
9. The value of form factor of Kunar river basin is found to be 0.1427 this indicates that it is a narrow basin. Pech sub-basin with form factor 0.53Kunar river basinshows wider basin while lower value of form factor0.096 of Chitral sub-basin indicates narrow basin.
10. Kunar river basin has the highest relief of 7157m and the lowest relief of 4765m and hence falls under high relief basin category. Relief inside the basin is low to moderate in the plains and high relative relief in the hilly area.
11. This studycan help usefully for water harvesting and watershed development, toidentifythe locations of dams and water storage sites for river management purposes, water supply, irrigation and energy production.

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