ASSESSMENT OF DIVERSE GEO-ENVIRONMENTAL PARAMETERS FOR MITIGATION OF AN UPPER CATCHMENT OF JHELUM RIVER BASIN, NORTH WESTERN HIMALAYAS, PAKISTAN

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ABSTRACT: For instituting a useful research cum database, a critical description of morhometric analysis was transformed for a better mitigation option. Analysis of streams order No. 2 displayed signatures of lithologic and structural control, knick points, non-symmetrical longitudinal profile, and high value of sinuosity index (1.75) besides orientation of lineament pattern that had depicted an interface of Cymatogenic uplift for drainage basin configuration. Notably, Kaghan Valley of the Kunhar River (KR) originated from shoulder of the Nanga Parbat. Resultantly, valley had undergone tectonic pressures, being tilted northeast to southwest and suffered severe compression so the drainage showed zig zag pattern with prominent knick points. The impact of KR was added silted flow into the Jhelum River that was custodian of Mangla, the country's hydal power producing facility. The activity of KR was a point of unique significance because its future behavior might take a different pattern depending on the changing morphology of the area. The present study was to analyzed morphometric status for predicted future behavior of KR drainage system. The data so provided was of immense practical value to develop a comprehensive strategy for implementation of water resources and sustainable development projects.

Keywords: Kunhar River, Geo-environment assessment, Drainage basins, Quantitative morphometry, Hypsometric analysis.

INTRODUCTION

Mountains are the main supplier of water for half of the world's population. It has been analyzed that the degradation processes which modify mountain landforms by weathering, mass movement, fluvial, and glacial action are all united to the distribution and movement of water in liquid, vapor, and solid phases (Price, 1981 and Wohl, 2000). To assess geo-environmental parameters, morphometric study of landforms provides important information about the evolution of drainage basin. However, if a specific basin is tectonically unstable, its morphometric analysis acquires extraordinary importance. Such is the case of Kunhar River basin, which constitutes 154 km northeast to southwest an elongated Kaghan Valley (KV) covering an area of 2650 km², placed between latitude N 34°10' and 35°10' and longitude E 73º15' and 74°10' respectively, as a part of the western terrain of the Nanga Parbat (8127 m). The latter is the terminus zone of the great Himalayas where it adopts a sharp southward bend that affects structural framework of the region. Nanga Pabrat is the most active orogen, which is rising at the rate of 7 mm per year. Valley is bounded by Diamer District and Baltistan on the north, Neelum Valley of Azad Kashmir on the east, Abbottabad District on the south and southwest and Manshera District and Kohistan District on the West. KR is the main river while Balakot, Kaghan and Naran are the main towns of the Valley. Considering the total area of the catchments and other characteristics, it can be categorized as a large catchment basin shown in Figure-1. KV shows a complex geologic framework of erosional and depositional cycles. The present landforms and other geomorphic features developed within the watershed basin are largely the product of erosional/glacio-fluvial dissection. Kunhar River, a main geomorphic feature is revealed by an altitudinal difference of approximately 4416 m above mean sea level (amsl) between its origin near Lulu Sar (Babusur Pass) in the NE and the Tori Village, 674m amsl in the SW at the origin of Salol Nala.

Rainfall varies from 100 mm above Batakundi to more than 2000 mm at Balakot. Perpetual snow cover is present above 4500 m, where glaciers appear and avalanches take place. (Scally, 1992) who also identified that after the evaporation of slight extended segment of snow deposits, the large volume of snow concerted in narrow valleys and further topographic concavities provides a pocket-sized surface area and therefore melt gradually. This stored snow plays substantial role to the water availability in the perennial streams and also provides a good base for biomass productivity The eastern ridges are covered with perennial snow (above 4500m), and have large number of glaciers and glacial-lakes. Snow deposits have been witnessed till October and later in the valley bottom between Kaghan and Naran (Mansell and Moullin, 1986, Khan, 2009). However, eastern side is greatly prone to landslides, mudflows, snow creep and debris flows, snow avalanches and other hazards that constantly are damaging the infrastructure mainly the leading Balakot-Kaghan- Babusar and Chilas roadway. Besides, the degree of human activities i.e. infrastructure development, dam construction, agriculture and mining activities that puts strong influence on landform/ land cover development in mountains which are controlled by the distribution of water (Hooker, 1980).

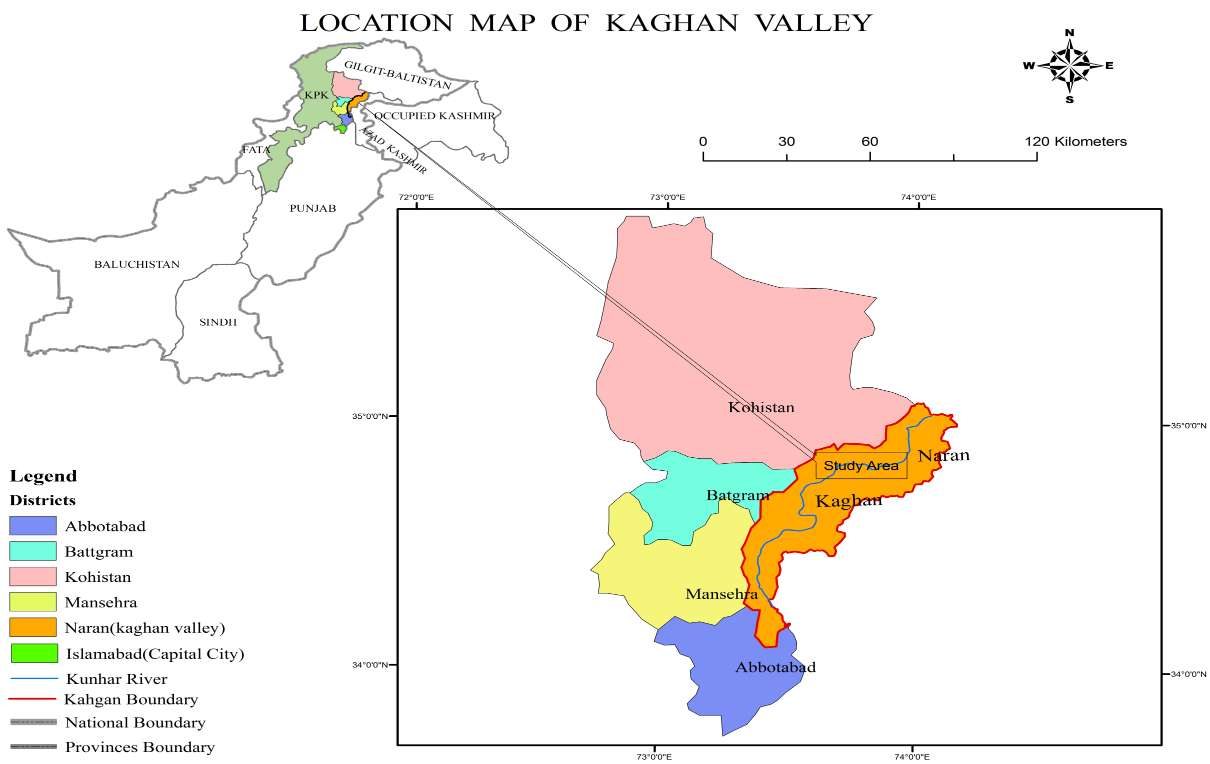


Fig.-1: Kaghan Valley (Kunhar River) map and its location in the Northern Pakistan (Source: Geological Survey of Pakistan and Satellite Image).

MATERIALS AND METHODS

On the basis of Reconnaissance Soil Survey of Kaghan Valley (RSS-KV, 1986) and by using previous information of the study area, training polygons were delineated on the rectified image to manipulate later as seed pixels for entire image classification. Geospatial datasets were utilized for achieving the useful research results such as Topographic Maps, covering the entire KR watershed basin, Landsat Images, Thematic Mapper dated 07.10.2001 and Enhanced Thematic Mapper of dated 19.09.2009, Digital Elevation Model (DEM): SRTM at 3arcsec spatial resolution. Similarly, field data, acquired from physical survey and qualitative to rigorous quantitative morphometric techniques were used for manipulation of acquired data. Data was presented with the help of GIS/RS techniques and graphic software. After the initial processing and truncation of Geo-spatial datasets on the AOI (Area of Interest), digital image processing techniques were applied on satellite image datasets for delineation of drainage pattern, landform classification, geologic framework, slope and aspect and Digital Elevation Model. A key facet in transforming satellite images into maps is that satellites provide physical and functional descriptions of the earth. Kutzer (2008) analyzed, both descriptions referred to as land cover and land use respectively was often mixed up. Image classification is a process in which all the pixels in an image that have similar spectral signatures are identified. In supervised classification classes are recognized in the scene from previous knowledge or identified by using thematic maps or actual on-site visits. Land cover groups so as to appear fairly identical on the image were positioned and bounded by polygonal limits drawn on the satellite image. Categorization followed by statistical processing in which every pixel was evaluated with the diverse closest signatures and assigned to the category. To acquire slope and aspect maps for observation of the drainage, slope and terrain profiles of the KR and its main tributaries, Digital Elevation Model (DEM) was constructed. To produce meaningful research cum data base, a detailed and critical description of drainage and tributary net-work was transformed from a purely qualitative to a rigorous quantitative geomorphology. By the existing information and field checks, geological description of the specific valley was marked and calculated. various unique features were identified by (Klemes,1990; Krecek, 1996 and Wohl, 2010) that put mountains separate specifically in terms of their hydrology.

A geological and geomorphological frame work was extracted and area calculated by supper imposing on map compiled by (Greco and Spencer 1993). Systematic description of the geometry of a drainage basin and its tributary-channel system required measurements of linear aspects of the drainage network (Tamma 2012). With the help of the recognized methods (Horton 1945, Strahler 1956; 1958 and Vijay 2003) the drainage network of Kunhar drainage basin for both linear and aerial parameters were analyzed. An effort was made to quantify the fluvial dissection of KR watershed basin. Systematic morphometric study including drainage; altimetric; hypsometric and lineament analyses was carried out and the results are discussed. To analyze accurate elevation of the intersections, topographic maps of the Survey of Pakistan on a scale of 1:50,000) and digital three sets of TM data of 2001, 2009 and 2013 on a 30m pixel resolution were obtained from the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), Pakistan were used. With the GIS/RS techniques, various data layers were plotted on the KV map to acquire reliable information. A total area of about 2,650 km² was selected for classification of land cover classes and demarcation of 19 sub-basins. Digital Elevation Model was generated on the bases of various data layers. Taking into account the role of elevation in confiscate water of a watershed, a weighted average value of entire basin was divided into half-inch squares and 286 central points of the area were counted.

RESULTS AND DISCUSSION

Drainage Pattern: Kunhar River of the Kaghan Valley is about 145 km long. Valley is an exceptional landform due to the wide range of altitudinal differences. KV is the product of KR and its prominent tributaries that constitute sub valleys within the valley. The River flows their course from the northwestern fringe of outer flank of Himalayan Ranges to westward for about 100 km and then suddenly changes its direction towards south at Manur Nala that categorized by angular bending shown in Figure-3. Near Manur Nala the valley expands its floor with maximum width of about 65 km² and finally proceeds westward near Balakot. After crossing Balakot, the river turns and flows on a plain land and broadens in the bad-land topographic feature near Ghari Habibullah. Braided bars and point bars are well developed in the lower reaches of the streams and near its confluence with the Jhelum River before it enter the gorge west of Lahor Gali. The upper reaches of the valley shows a narrow basin, about 50 km from its source Lulu Sar near Babusar Pass to Burawai towards northeast. Rapids, cascades and waterfalls in the upper reaches of the valley floor indicate the streams.

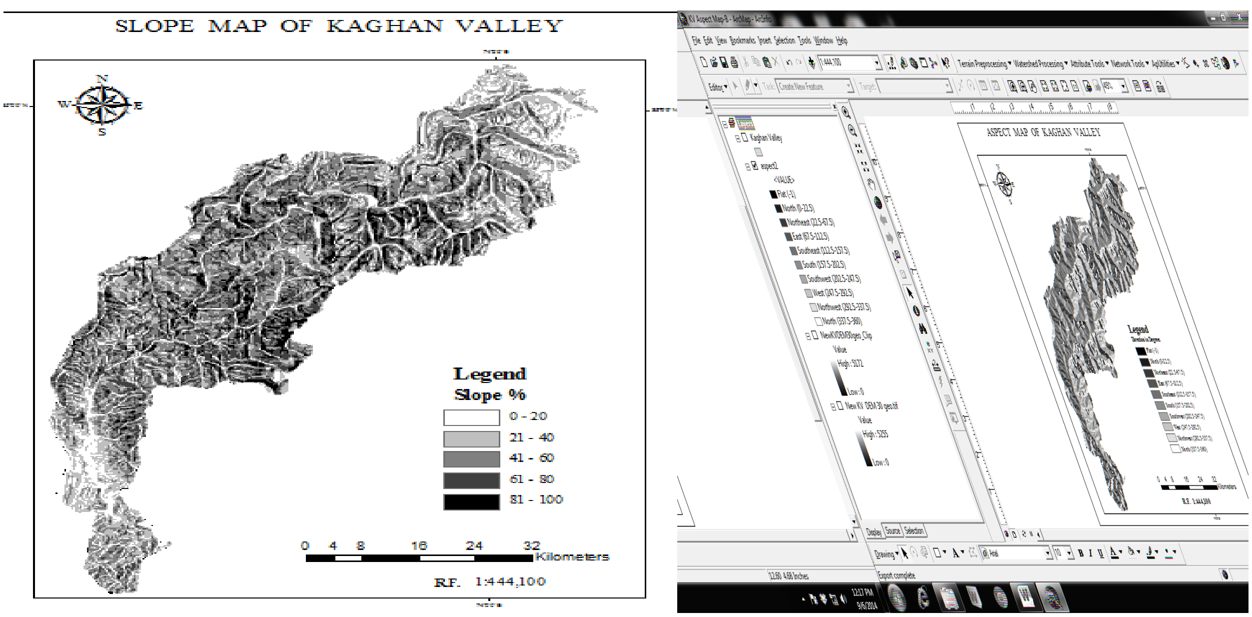


Fig.-2: Showing DEM derived directions of slopes from North in degrees

Cascades and waterfalls are developed in the stream bed near Saiful Maluk Nallah with prominent free face and plunge pool in the higher reaches, Gorges are also developed. The streams are perennial in nature and mixed pattern from parallel to sub parallel, trellis, and radial can also be predictable within the watershed basin.

Litho-Geologic Framework: Valley is placed between the upper altitudinal zones in the Higher Himalayas, while lower zone is in the Lesser Himalayas. The tectonic influence of the Nanga Parbat is rather severe and clearly identifiable. It was assessed that variations in mountain environments over short, horizontal and vertical distances are universally recognized as central to controlling mountain hydrology (Khan *et al.,* 1995, 2002). Therefore are representing a remarkable contrast of geo-environment.

Satellite Image-overlaid Kunhar River and Saif-ul Maluke Nallah

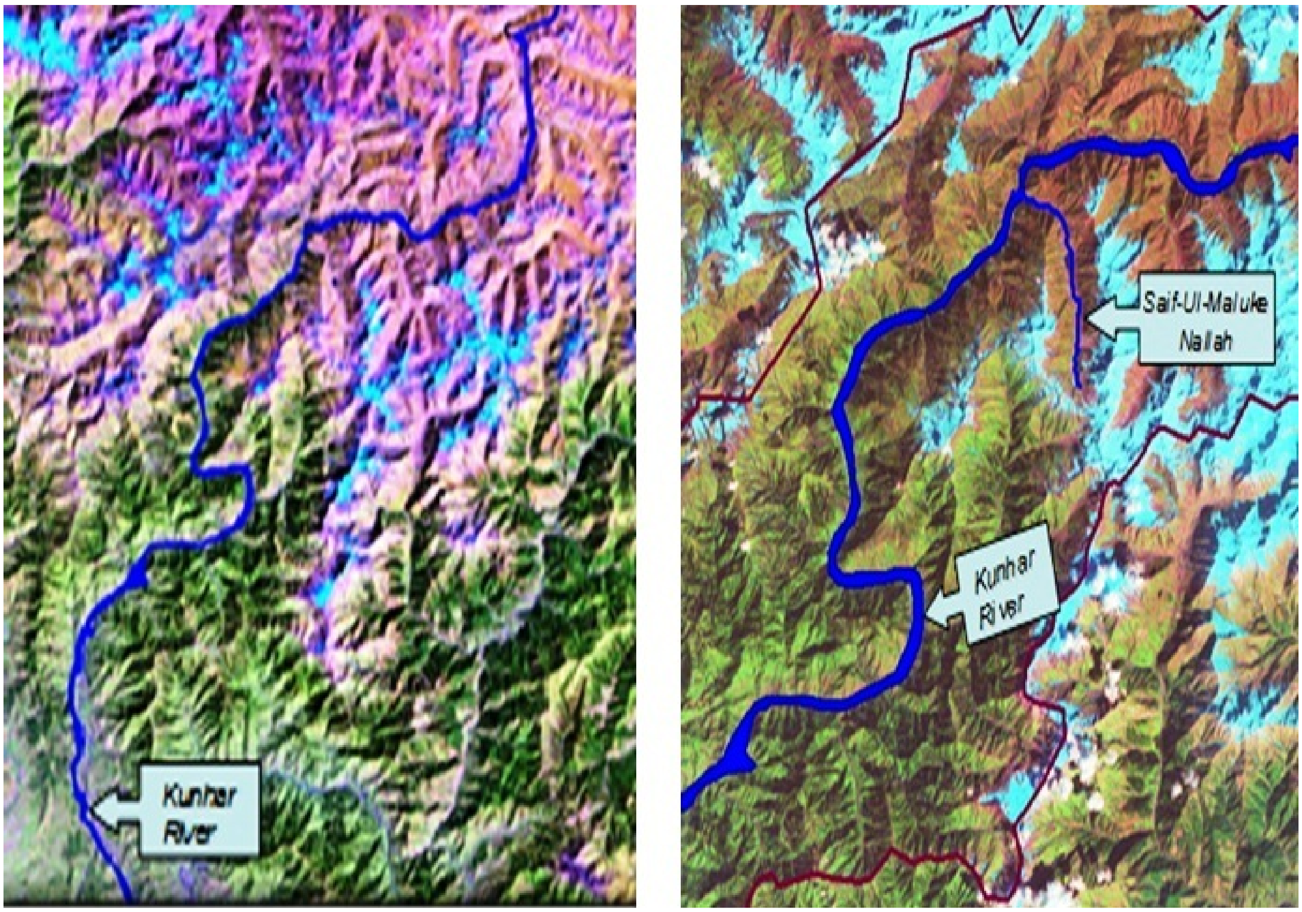


Fig.-3: Depicting longitudinal profiles of the Kunhar River and its angular bending and Saiful Maluk Nallah leading free face & plunging pools

Just down to Naran The Main Central Thrust (MCT) crosses the Kunhar Valley near Paludran and crosses over the upper part of the Manur nala catchment that originates at about 4400 m above mean sea level (amsl) and joins the main KR at Mahandri about 1530 m amsl. Punjal Thrust (PT), Main Boundary Thrust (MBT) and Main Mantel Thrust (Melange Zone) altogether establish the major boundary faults. The geomorphic status of the Valley is largely controlled by very active tectonic forces that are persistently at work in the region. All the major Himalayan Thrusts cross this Valley. October 8th, 2005 Earthquake was one of the major tectonic events of this century that obstructed a large part of the valley. Paras (1645m amsl), a valley town always remains under the influence of both Panjal Thrust and Main Boundary Thrust as both cross close to this valley town. The Kashmir Boundary Thrust (KBT) and the Indus Kohistan Seismic Zone are within 15 km of Paras. Consequently, any significant activity on these faults could alter the valley landforms and finally affect the community. Due to its location near to these active thrusts the valley is prone to persistent land sliding whereas, type of land sliding depends on litho-stratigraphy and tectonics. The earthquake of 8th October, 2005 reshaped the valley and damaged villages and towns causing heavy casualties and loss to property.

Kashmir Boundry Thrust (KBT) or Muzzafrabad Fault is an active thrust that crosses Muzarrabad and Balakot. The epicenter of the October 8th Earthquake was located on this fault. The earthquake had activated hundreds of land slides. A time frame from Pre-Cambrian Salkhalas to Miocene Murree Formation rocks framed the valley soil formation. Structurally, nearly all interactions are faulted. The agglomerate slates appear to indicate volcanic-sedimentary material.

Quantitative Geomorphology: Geo-Environmental phenomenon that is responsible for the sculpturing of land surface, produce surface geometry from which numerical data can be obtained. It was identified that the factors affecting runoff generally tend to cause most large drainage areas to behave differently from most small drainage areas on the basis of hydrologic behavior (Chow, 1954 and 1959). The prominent physiogrphic contrast in the KV occurs that affects the vegetation. The eastern ridges are covered with perennial snow above 4500 m, and have large number of glaciers and glacial fed-lakes. This side is also much prone to landslides, mudflows, snow creep and debris flows. Snow avalanches and landslides continuously damage the infrastructure, especially the main Balakot-Kaghan-Babusar and Chilas roadway. These glaciers occasionally develop small ponds of snowmelt water that get dammed due to blockage by loose rock material. Where, such glacial ponds due to certain geoenvironmental factors get busted, a glacial lake outburst (GLOF) caused rock and mud slurry rushes down the slope causing damage to life, infrastructure and property. After the disastrous September 1992 flood in KR due to heavy rainfall, another disaster Glacial Lake Outburst struck on 10 July 2001 in the form of Chitta Kataha GLOF that blocked the normal flow by creating mud dam on the KR for about 11 hours and caused great loss to the property and infrastructure. To formulate a rational for both streams and their basin configuration a number of researchers and workers examined with the opinion of analyzing drainage system. However, (Horton, 1945) first initiated a unique idea for stream classification that is globally accepted. Followed researchers (Strahler, 1956; 1992; Morisawa, 1968; Scheidegger, 1965) accepted this approach to geomorphology as an authenticated and workable approach. More recently, (Wright *et al.,* 2000; Gritzner *et al.,* 2001; Marcus, 2002) noted that application of hydrologic modeling could take into consideration geomorphological parameters including stream classification using GIS. A research was made to quantify the fluvial dissection of KR watershed basin taking following parameters: -

Drainage Analysis: The most dynamic part of any watershed is its streams networking. Identification of the stream order is an essential requirement in the drainage basin analysis as introduced by Horton (1945) and slightly modified by Strahler (1956). For computing the ordering system of the stream network of KR drainage system all small fingertip streams were considered as 1st order and joining two 1st order streams, where length was more in comparison to the first one was given as 2nd order (Vijay, 2003) and so on. In these order system, the main stream was put in 7th order and maintains its order throughout the whole course.

Table-1. Selected tributaries of the Kunhar River Sub basin (out of 19), their stream orders and Bifurcation Ratio (Rb) for Different no. of Streams

S. No	Tributary (Stream)	Sub Basin No.	Drainage Density (D)	Order Number						Rb	Constant of Channel Maintenance (C)
				1	2	3	4	5	6		
1	Glttidas Nala	1	3.8	377	91	23	5	1	0	4.1	0.26
1	Sapat Katha (Batakundi) w	7	5.6	682	151	23	7	2	1	4.5	0.17
2	Saiful Maluk Nala (Naran) E	9	6.4	263	67	16	3	1	0	3.9	0.16
4	Bhimbal Katha (w)	10	6.8	705	129	26	5	2	1	5.5	0.14
5	Manur Nala (Mahandri) E	12	4.3	823	189	37	8	2	1	4.4	0.23
6	Chushal Katha (Jared) w	15	7.0	113	24	6	1	0	0	4.7	0.14

To work in detail KV has been divided into 19 sub drainage basins and six sub basins have been selected as further analysis. Using these above established parameters, the stream order numbers were given to the selected tributaries of KR and are documented (Table 1). Yet, it permits an assessment among stream order and structural system. Total number of streams encountered order wise for entire basin. Log value of stream number plotted against stream order created a straight line shown in Figure-4 that satisfies Horton's law for study area. The stream section of the highest order chosen as the main stream was the one through which main discharge of water and sediments were passed. According to (Strahler, 1956) "order number is dimensionless, two drainage networks differing greatly in linear scale can be compared with respect to corresponding points in their geometry through use order number". By these recognized factors, the stream order numbers were given to the selected tributaries of KR and are presented in Table-1.

Streams Length: The lengths of various streams were measured and calculated order wise, the total length as well as the mean length were computed. However, the average length of stream increases with the order in direct proportion. It was defined that the stream length of a given order are inversely proportional to the stream order (Strahler, 1958; 1964). The connection between total stream length of a given order and the stream order was a power function and plotting the logarithm of total streams length of a given order against the logarithm produced a straight line and indicated a linear relationship shown in Figure-4. Data identified, almost all the values as the straight line excluding the 5th order value. This fact might be related to the greater length of particular 6th order streams as compared to the lower order streams due to headword erosion, which was used on zones of structural weakness.

Bifurcation Ratio (Rb): It describes the ratio of the number of streams of a given order to the next higher order. It generally shows the rate of change of number of streams with respect to order. The bifurcation ratio for different order of streams along with the number of streams of the KR basin was calculated by using formula as:-

Rb: whereas, Nu= Number of segments of given order,
Nu + I=Number of segments of higher order.

Total number of all corresponding stream sub basin was 3,018 while average bifurcation ratios was 4.6. Evaluating the Rb, whole basin fluctuated from 3.9 to 5.5 with 1st order to 6th order stream with a mean value of 4.6. That was a clear indicator of the steep physiographic status of the study area while Rb in the lower order was in constant state shown in Figure-4 and Table-1. The average Rb for 1st order to 4th order streams has signified an elongation stage of the basin. The higher Rb of 5.4 of 5^{th} order and 6^{th} order stream has recommended structural or lithological control for drainage basin development (Strahler, 1964; Mekel, 1970; Strahler, 1992).

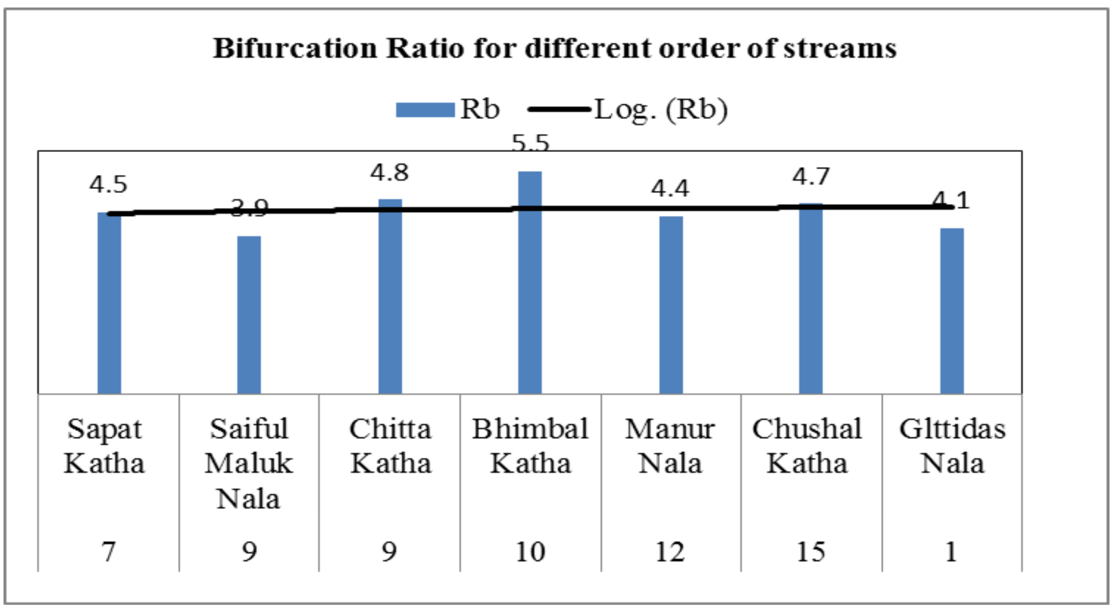
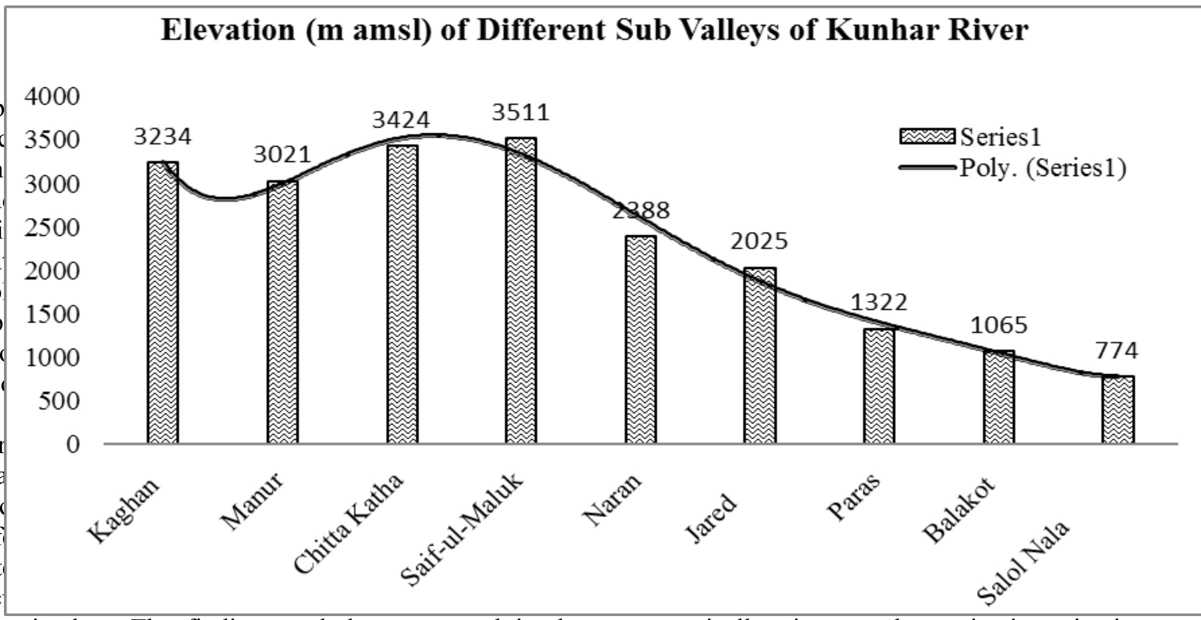


Fig.-4: Selected Sub basins, stream orders and Rb of different no. of streams, the logarithm straight line trend showing clear indicator of the steep physiographic status

Drainage Density (D): The ratio of total channel length of all orders to the area of the basin is defined as Drainage Density (Strahler 1958, Vijay 2003, Bassey and Joel 2010). It is realized an indicator of the closeness of spacing of channels in the watershed basin (Rajiv 2005). Simultaneously, it highlights the exclusive liaison between landforms, rainfall, runoff and infiltration capacity. It also contributes useful evidence about the tectonic activity as well as lithologic structure of the watershed basin (Khan, 2002). For various analyses, the watershed was sub-divided into nineteen micro-catchments. The acquired data was computed and the results were shown in graphic form that showed inversely proportional relationship to stream order except the value of drainage density for Chushal Katha (Jared), 15th order basin i.e. 7.0 shown in Table-1. However, for individual sub-sections of the watershed basin, it ranged between two extreme values i.e. 2.4 to 7.0. The DD value (7.0) significantly increased and DD value (2.4) decreased due to litho- tectonic and structural control as well as climatic factor of the mountainous region. If the value of DD is less than 5.00, it will depict coarse material, between 5.00

to 13.70 medium and 13.71 to 155.33 fines and > 155.33 ultra-fine soil material respectively. Average DD of the KR watershed was 5.1 that was indicator of coarse and medium category according to Strahler, (1957). It was noted that the sub basin areas with comparatively higher density were more prone to erosion with thin vegetative and patchy soil cover. Elevational difference of the watershed shown in Figure-5 was the product of fluvial dissection by streams that could be observed as polynomial trend of high in the upper reaches, low in the lower reaches. It is observed that the mean basin area increased as the order of stream increased in direct proportion. The constant of channel maintenance (C) was calculated as 1,034.4 ft² and presented in Table 1. It was observed that the value of C is inversely proportional to the order of stream. This factor may also be related to the geotectonic and structural control for the development of the basin. Considering aforementioned factors, drainage density of the basin was calculated by using formula: -
D=L/A whereas: L= Length of the channels in miles; A=Area of the basin in square miles

Hypsometric Analysis: To calculate the true elevation of the intersections, topographic maps of the Survey of Pakistan were used and the average of these points showed the average relief/elevation of the KR watershed calculated weighted average elevation as 1,12,395′.



numeric data. The findings and data presented in the study permits to re-evaluate as well as reconstruct the geomorphic background of the northeastern and eastern part of NW Himalayas folded region, on which KR basin of the KV has emerged. Geodetic data suggests that the Himalayas are still undergoing vertical uplift at an average rate of about 0.8 mm. $yr.^{-1}$ (Verma, 1991). However, slow rate of erosion 0.2 mm. $yr.^{-1}$ calculated (Glaser *et. al,* 2012) over the past 40 m.y. against the high rate of erosion (0.62- 1 mm. $yr.^{-1}$) at present in the Himalayan region noted by Sharma, (1984) that supports various phases of uplift. This phenomenal rise is considered so great that considering the period since its emergence, the Nanga Parbat should have risen 7 km high. However, the rate of erosion is also so strong that its height is kept at a reasonable level, presently of 8127 m, which still makes it the 8^{th} highest mountain in the world. The fast uplift of Great Himalaya after the Middle Miocene resulted physiographic barrier for the wind. Due to tectonic activity of the Nanga Parbat, the KV remains under its persistent influence; its eastern side tectonically; its morphometric investigations procure unusual significance. Such is the case of KR, an upper catchment of Jhelum River watershed that constitutes 145 km long northeast to southwest KV as a part of the western terrain of the Nanga Parbat (Khan, 2009). Similarly, (Walsh *et al.,* 1998) has defined the persistent debris-flow activity along the active Liacher Fault on the western shoulder of the Nanga Parbat. The latter is the terminus zone of the great Himalayas where it adopts a sharp southward bend that affects structural support of the area. Moreover, Nanga Pabrat is the most active orogen that is rising fast. (Goudie, 1990) identified exceptionally steep slopes from 1500 m valley floors and mountain peaks 7000 m and above. Thus, weathering is intense and mass erosion realized as thick valley-fills above 700 m or so. It was suggested that fission track data of uplift rate (Nanga Parbat massif in the main syntaxis) on NW Himalayas has amplified over the past 7 Ma from under 0.5 mm/yr to over several millimeters per year (Zeitler, 1985). This has been endorsed to its phased uplift and the high rate of erosion. Shroder, (1993) indicated, the total volume of sediment shed into the Indian Ocean over the last 40 million years through the activity of Himalayan watershed system is about 8-5 10^6 km^3, giving an annual erosion rate of 0.2 mm/year. The DEM derived overall aspect of KR basin is eastern on the right bank and western on the left bank. Aspect map shows direction of slope from North that corresponds from –1º to 359.996º shown in Figure-2. The maximum slope of the valley is more than 80%. This gives a remarkable gradient of about 20m per km to the Valley (Khan, 2006). Longitudinal profile of the KR has portrayed its dynamic nature of existence (Fig.-3). The physiographic elevation is evident due to glacio-fluvial erosion that took place due to geotectonic uplift of the Himalayas. The erosion is very high; the present rate of 34.4 tonnes /ha/year, (about 1,381,522 tonnes) of sediment (WAPDA, 2004) is being shed into the Mangla surface reservoir an energy-generating facility. Therefore, all elements including the climate remain in continued flux of change, which produces a unique dynamic element.

An altitudinal difference of about 4900m between its origin near Babusar Pass in the NE and the Tori Village 674m amsl in the SW at the mouth of Salol Nala was a clear indicator of geotectonic activity (Khan, 1998; Khan *et al.,* 2002; 2006). Loessic plain at the western part i.e. Shongran and Lalazar are the prominent planer surfaces. Other small plane surfaces had determined sign of the surface erosion. Likewise, many earth scientists, (Devantier *et.al.,* 1993) emphasized Digital Analysis Models; the best utilization of elevation data is by using point, contour line or triangulation networks. A systematic investigation of the drainage system reveals the vital role of the glacio-fluvial processes in accordance with the various laws of Geomorphology formulated (Horton 1945). A long-term process of fluvial dissection is mainly responsible for the development of valley floor. A tectono-structural control in the development of stream's network was apparent from straight segments of tributaries and sharp angular turnings in sinuous bends and knick points along with entrenched meandering. Streams order Two (2) Identified testimonies of lithologic and structural control, non-symmetrical longitudinal profiles, knick points, high value of sinuosity ratio 1.75 and alignment of lineament design better defined a repercussion of Cymatogenic uplift for watershed configuration. This trend proposed that the watershed has experienced rejuvenation largely due to Cymatogenic uplift. Similarly, Hypsometric analysis supported the conclusion that the KR watershed as a whole signified the "monadnock" stage of creation. The longitudinal profile of the Kunhar River shows knick points at the altitudes of 4000′, 6000′, 6500′ and 8000′ respectively Moreover, existence of knick points marked by cascades and waterfalls above 4000′ support this conclusion.

Both Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) Sensors have corresponded to linear zones of tectono-structural weaknesses. Lineaments were identified on Landsat's Multi-spectral Imagery datasets. The lineament patterns for the entire Valley watershed indicated that deformation as well as restructuring has been the outcome of combined regional compression and vertical hosting (Power *et al.,* 1980). Tectonic movements might be the governing source for deformation and restructuring of layers of rocks for the formation of mountainous ranges. Straight segments related with higher order tributaries could be supposed as structurally controlled for their development. KR watershed deformation is related to India-Asia collision and subduction of Indian Plate under Asian Plate. Evaluating the Rb, entire watershed fluctuates from 3.9 to 5.5 with 1st order to 6th order stream with a mean value of 4.6. That is a strong indicator of the steep physiographic status of the watershed area. The average Rb for 1st order to 4th order streams signifies an elongation stage of the watershed basin. The higher Rb of 5.5 of 4th order streams (sub watershed basin) suggests structural or lithological control for drainage basin development (Schumm, 1956; Strahler; 1964, Mekel; 1970; Strahler, 1992). Existence of river terraces in the upstream, knick points, waterfalls, gorges and rapids are indicators of rejuvenation. Geotectonic movement in this region during Neogene time is related with this rejuvenation. The value of sinuosity index of the KR and other sub order tributaries of this watershed basin are above 1.5 that is indicative of entrenched meandering; an indication of rejuvenate stage of basin development.

An integrated multi-sectoral approach is more essential for monitoring and sustainable development in mountain areas that had limited development opportunities (Khan *et al.,* 2009). The research has provided a scientific clarification to better realize the physio-geographic-morphometric setting in the study area and also will contribute basic information to reconstruction, rehabilitation and revitalization process in the vulnerable areas. Study also has unfastened several opportunities for working out an improved strategic planning and mitigation measures. Dynamicity of KR watershed strongly suggests a multidisciplinary and interdisciplinary planning to encounter the multifaceted issues that have been intensified to a serious stage.

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