APPLICATION OF GEOSPATIAL TECHNOLOGY IN THE DETERMINATION OF NEOTECTONICS OF CHITRAL VALLEY, HINDU KUSH AREA NORTHERN PAKISTAN

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ABSTRACT*:Chitral valley is situated in the NW corner of the collision region of Indian and Eurasian plate, Hindu Kush Range, northern Pakistan. It is one of the most tectonically active regions because of the abduction processes of Eurasian plate. Intermediate depth earthquakes are routine practice here. Mapping of Neotectonics is an issue of concern now a days. Neotectonics help us in assessing of seismic hazards and to understand the nature of the deformation of the region. The main purpose of this research is to detect the active and neotectonics of Chitral Valley. For this purpose, 90 m SRTM DEM is used for automated stream generation. Geomorphic indices of steam profile analysis are analyzed in MATLAB over the stream network of study area, steepness and concavity maps are the final output. The resultant computed maps are quite helpful for the analysis of active tectonics as erosion and uplift of the study area. Further drainage density is calculated in order to verify the former results. All the minor and major streams were analyzed. With the help of these geomorphic indices it is concluded that a drainage network of study area is totally tectonic induced and deformed because of active tectonics. Areas of active deformation along the major faults are also marked.*

Keywords: Neotectonics, Chitral, Geomorphic Indices, STRM DEM, MAT LAB.

INTRODUCTION

Morphometry is defined as a branch of science which deals with the measurement of landscape metrics and their analyses [1]. It is the state of the art, analytical and illustrative way to represent surface of the earth by the algorithmic management of terrain height [2]. Geomorphometry is a multi disciplinary field that has progressed from the combination of three fields of basic science. First is mathematics, secondly Earth sciences, and most recently computer science. Geomorphometry is no longer just an collection of numerical techniques, but a discipline in its own right as it has been detected as an activity within more renowned fields, extending from geography and geomorphology to soil science and military engineering and other emerging fields. Tectonic Geomorphology is the main cause of evolution of mountainous landscape. Neotectonics is defined as a science which implicates the study of the deformation and the motions of the Earth's crust, which are current or latest in geologic time scale. While studying Neotectonics both Geological and Geomorphological processes are reviewed.

Erosion and Uplift

The equilibrium among erosion and rock uplift is the fundamental principal of tectonic geomorphology. Mostly, landforms in dynamically deforming areas are the result of this relationship.The shifting of the vertical location of a point on the land surface at any time is calculated with the help of:

a) The proportion at which bedrock is being carried upward by tectonic processes (known as the "bedrock uplift rate")
b) The degree at which material beneath the ground surface is compacting and compressing
c) The rate of denudation or deposition of sediments, over the earth surface.

Surface uplift is equal to the bedrock uplift plus deposition, as compaction and erosion has been detected from deposition. Bedrock uplift and deposition plays a vital role in rising of the land surface, while erosion, compaction and bedrock subsidence serve to lower it. Earth's surface uplift or depressions usually refered as variations in the elevation of a earth surface.However, bedrock uplift commonly taken as the change in the vertical position of rocks with respect to a fixed reference frame, such as the geoid. Rates of erosion are generally defined in terms of depressing of the bedrock surface[3,4].

Drainage Density

Because of the continual interaction between surface runoff and the factors responsible for the resistance of a drainage area (rock, soil, plant cover), drainage density is an important feature of drainage systems from both the geomorphological and hydrological viewpoints. From the geomorphological point of view, a river network is an element of the landscape, its spatial distribution on a drainage basin influencing relief fragmentation and to a great extent the types and intensities of certain geomorphological processes. For hydrologists, drainage density plays a significant and important role in surface-runoff processes, influencing the intensity of torrential floods, the concentration, the sediment load and even the water balance in a drainage basin. Drainage density is assessed in terms of the number of streams on the one hand, and their length per unit area on the other**.**[5]

While focusing on the upper mentioned rules, this paper is designed on the Neo tectonics of Chitral District, KPK, Pakistan. As it is one of the most seismically active regions of Pakistan.

Objectives

- Identification and demarcation of active deformation using remote Sensing approach, in Chitral (Eastern Hindu Kush) Region,
- To prepare Concavity, Steepness and drainage density maps in order to constrain active tectonics
- To determine whether the drainage pattern is climatic induced or tectonic one?

Study Area

Chitral district is one of the biggest districts of Khyber-Pakhtunkhwa. It covers a region of approx. 14,851 killometers². To the east it bonds a boundary by Gilgit-Baltistan , towards the north and west with Afghanistan, to the south with Swat and Dir. In the north Chitral is separated from Tajikistan with thin strips of Wakhan Corridor[6].

Chitral is counting up among the highest areas around the globe, far-reaching from 1,093 m at Arandoo to 7,727 m at Tirich Mir, and also having more than 39 peaks which are 6,101 m in height. Chitral's topography is mostly hilly and rocky. In the north of the district, is Tirichmir which rises up to 7,727 m (25,290 ft.). It is most elevated peak of the Hindu Kush range. About 4.9% of the area is composed of woodland and rest of the area comprises of glaciers and mountains.

Chitral links with Pakistan by two highway courses, first is by Lowaari Pass (10,231 feet). Second one is Dirand Shandoor Top (12,201 feet). Both of the courses are completely blocked in snow season[7].

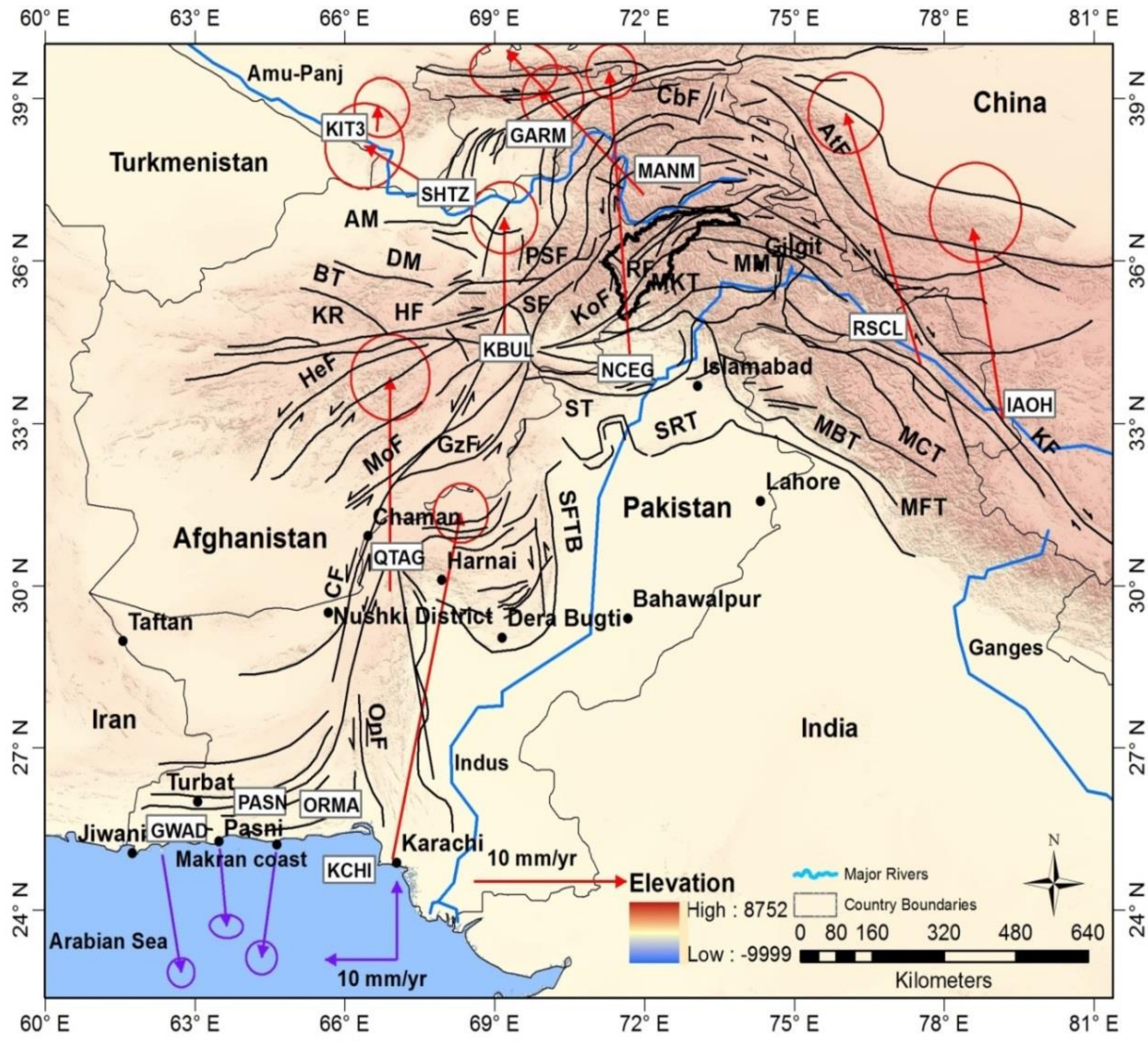


Figure 1: Regional tectonic framework (Hindu Kush-Himalaya-Pamir-Karakorum) with boundary showing the study area. Recreated after [8]

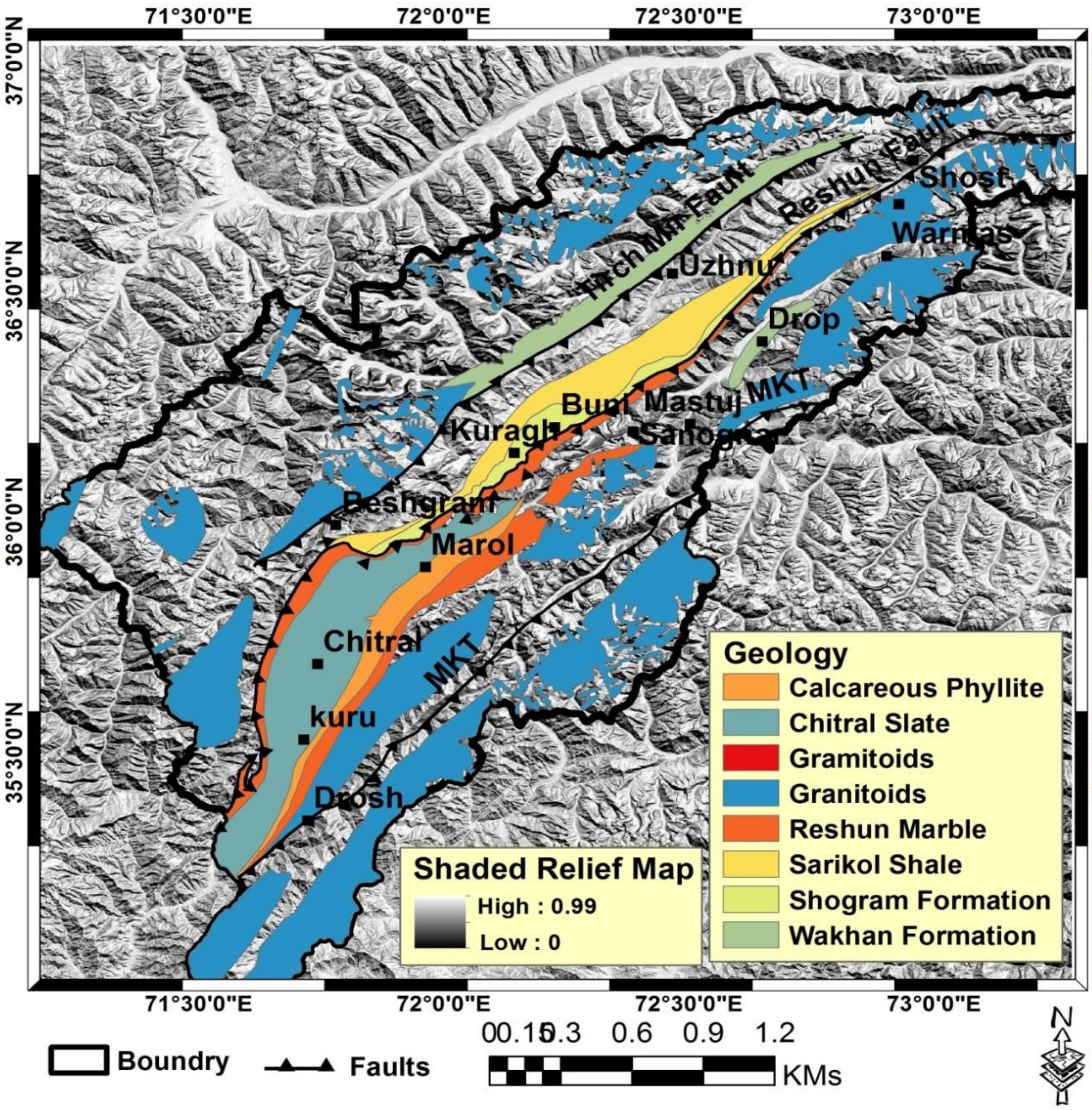


Figure 2: Geological map of Chitral district. Digitized from Geological map of Chitral District NWFP, Pakistan 2000 Geological survey of Pakistan (GSP)

MATERIAL AND METHODS

This research is based upon the DEM, obtained from, Shuttle Radar Topography Mission (SRTM, version 4) 3 arc second digital elevation model (DEM) data from NASA, with a 3-D spatial resolution of 90 m, downloaded from USGS site as its free available there.

Sink and holes were removed from the terrain model in first step by using Arc GIS 10.1. In next step extraction of drainage network from DEM using Eight Directional Method in River Tools was done. In further steps Stream Vectorization, Stream Strahler Ordering Flow directions, up slope area and the catchment area is also calculated

D-8: The renowned D8 script has been used to estimate pour point courses on a landscape, and this technique trails flowpaths from every individual DEM grid cell to its 8 surrounding grid cells (Figures 3 and 4).

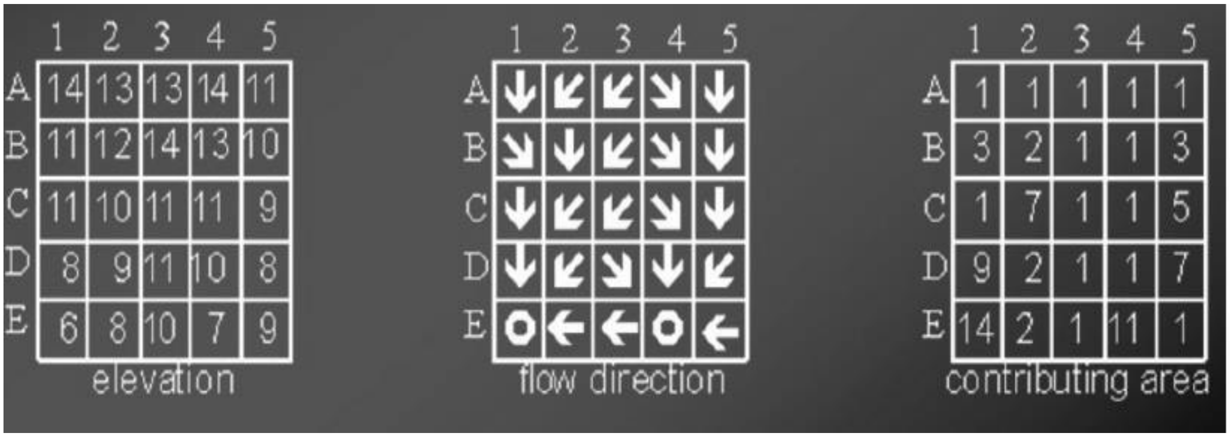


Figure 3: Mechanism showing eight direction methods.

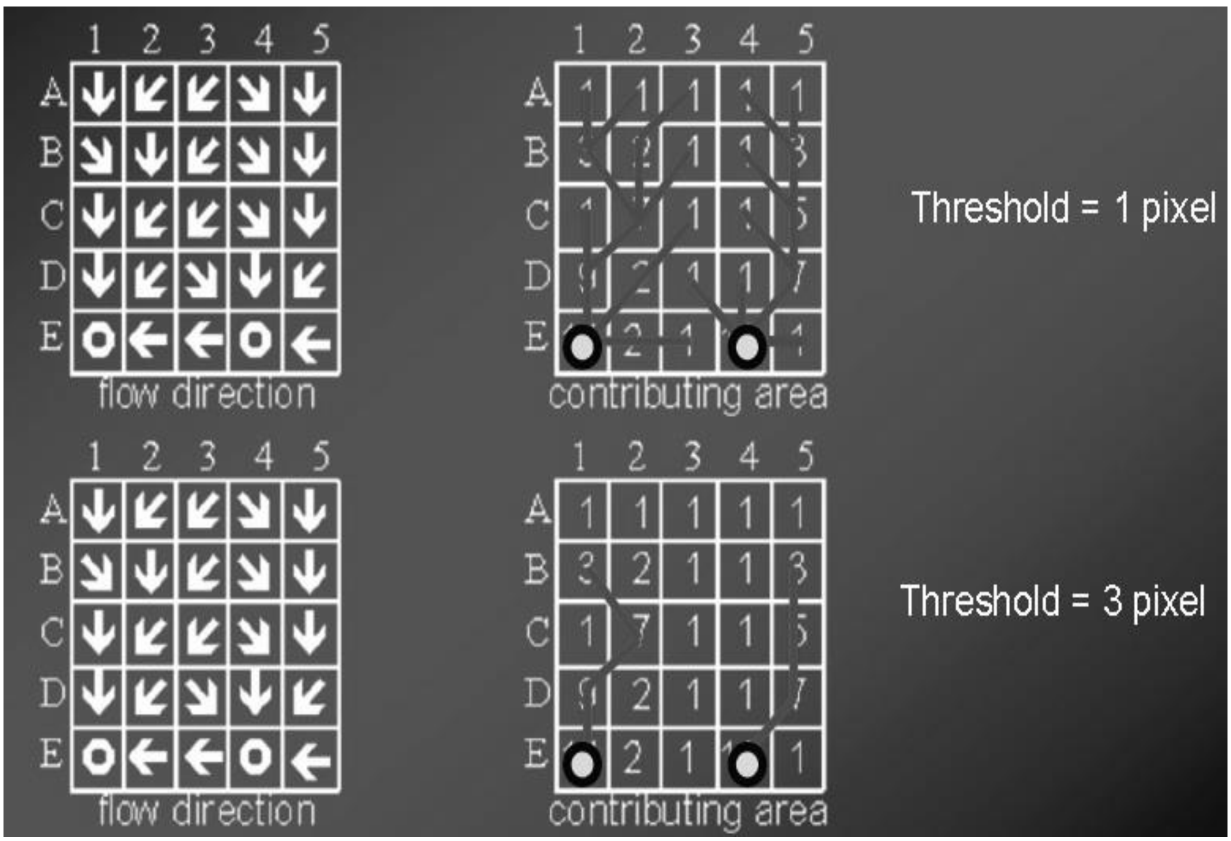


Figure4: Automatic extraction of drainage network using grid based and threshold pixel techniques.

Calculation of Concavity and Steepness Index

The computation of the relative uplift is made on the basis of stream power law of breaks in scaling which is frequently replicated as a detachment-limited incision model and its purpose regarding the accumulation of drainage area and stream-length gradient or Hack Index [9].

River longitudinal stream profile analysis (RPA) was executed on each and every single small or big stream to compute complete details about the concavity and steepness index. The formula running behind this model is as follow:

$$Rate\ of\ change\ of\ elevation = Uplift - Erosion \quad (1)$$

Equation (1) can be re written as:

$$\frac{dz}{dt} = Uplift - KA^{m}S^{n} \quad (2)$$

co-efficient pertaining to the rock strength variation and removable sediments. A is draining area and S is the slope of the channel. Watershed constants m, n are relying on basin geometry and erosion conditions. In a dynamic equilibrium scenario, dz/dt = 0. Therefore, equation (2) is as follows:

$$slope = \left(\frac{uplift}{erosion} \right)^{1/n} A^{m/n} \quad (3)$$

The factor (uplift/K)$^{1/n}$ is uplifting segment or channel convex up segment. m, n are the basin constants and corresponds to the concave-down segments. The equation 3 can be re-written as

$$S = k_s A^{-\theta} \quad (4)$$

While "θ, K_s concavity and steepness indices". By combining last two equation, the resulting relation is obtained to compute differential relative incision/uplift rates for the Hindukush.

$$Uplift = k_{sn}{}^{n} K \quad (5)$$

"Where k_{sn} is the normalized steepness index" Equation.(5) yields the comparative incision rates under steady state conditions for local topographic evolution by selecting appropriate standards for m, n and K. River Profile Analysis (RPA) was performed on the chosen convex up trends for every individual selected stream to compute θ, K_s. The slope of the regression is –θ and the intercept is logk_s. (Figure 5)

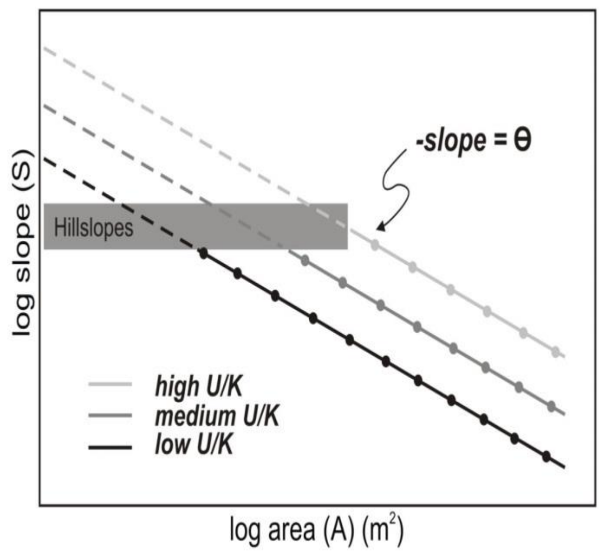


Figure 5: Diagram showing tectonic uplift and increase in hill slope processes note in all the cases, only the steepness changes and not the concavity.

RESULTS AND DISCUSSIONS

There are several areas of the earth where access is nearly impossible. That's why research over the geomorphology and tectonics of those regions is affected. Science always has to find a way so new techniques are developed in order to conduct a proper research on remote areas. The same has been done in this research for tectonics and drainage pattern determination of study area, which was our major concern.

There are different types of softwares available in order to work on tectonic geomorphological analyses. Stream profile analysis is used in this research for the generation of stream profiles, determination of flow direction, study of watersheds and calculation of knick points.

Power of stream profile analysis can be understod through the relationship between uplift rate and steepness in developed tectonic settings, and the ability to describe temporal and spatial breaks in rock uplift rate in more poorly compelled topography. Climatic and lithological information can also be used in order to calculate the variation in rates of rock uplift and steepness index. For further investigation in neotectonic stream profile analysis can be of great use.

Chitral district, is one of the remote and largely inaccessible areas of the world, is taken as the study area in this research. Eighty-six streams of Chitral district are analyzed with the help of stream profile analysis in order to get the information about the concavity(θ), steepness index(ks), and longitudinal profiles of th drainage network.

With the help of River tools, ERDAS Imagine, MET LAB, 90 m SRTM DEM of area is processed. In order to calculate the concavity, steepness and Drainage density, River Profile Analysis (RPA) were applied over the 86 streams of Chitral district. RPA provides us the steepness, concavity and drainage density data along with following details: a downstream change between different steepness values (or two convex up segments) is generally bridge with a high or low concavity. This changeover zone is because of spatially varying rock uplift rates or spatially variable lithologies. The non-equilibrium river profiles show numerous prominent knickpoints and few of them are traveled up-stream by the response of the channel due to increased channel incision, channel narrowing, increased sediment removal and the erosion of tectonics units. These profiles exhibit a disequilibrated behaviour due to the neotectonic activity along the fault traces those grounds a sensible phases of channel downstream. The results provided on the basis of further analysis are provided below.

Stream Profiles

Following profiles gives us the information of River profile, Area, Elevation and slope-area data. Sudden change in river profile give proves of presence of Nick point there. Nick point is the abrupt change in river profile; it is because of tectonic scarp or geological change. It has been identified many knick points on each profile and their diverse distributions on the map view is important to see the tectonic/lithologic contrast [10].

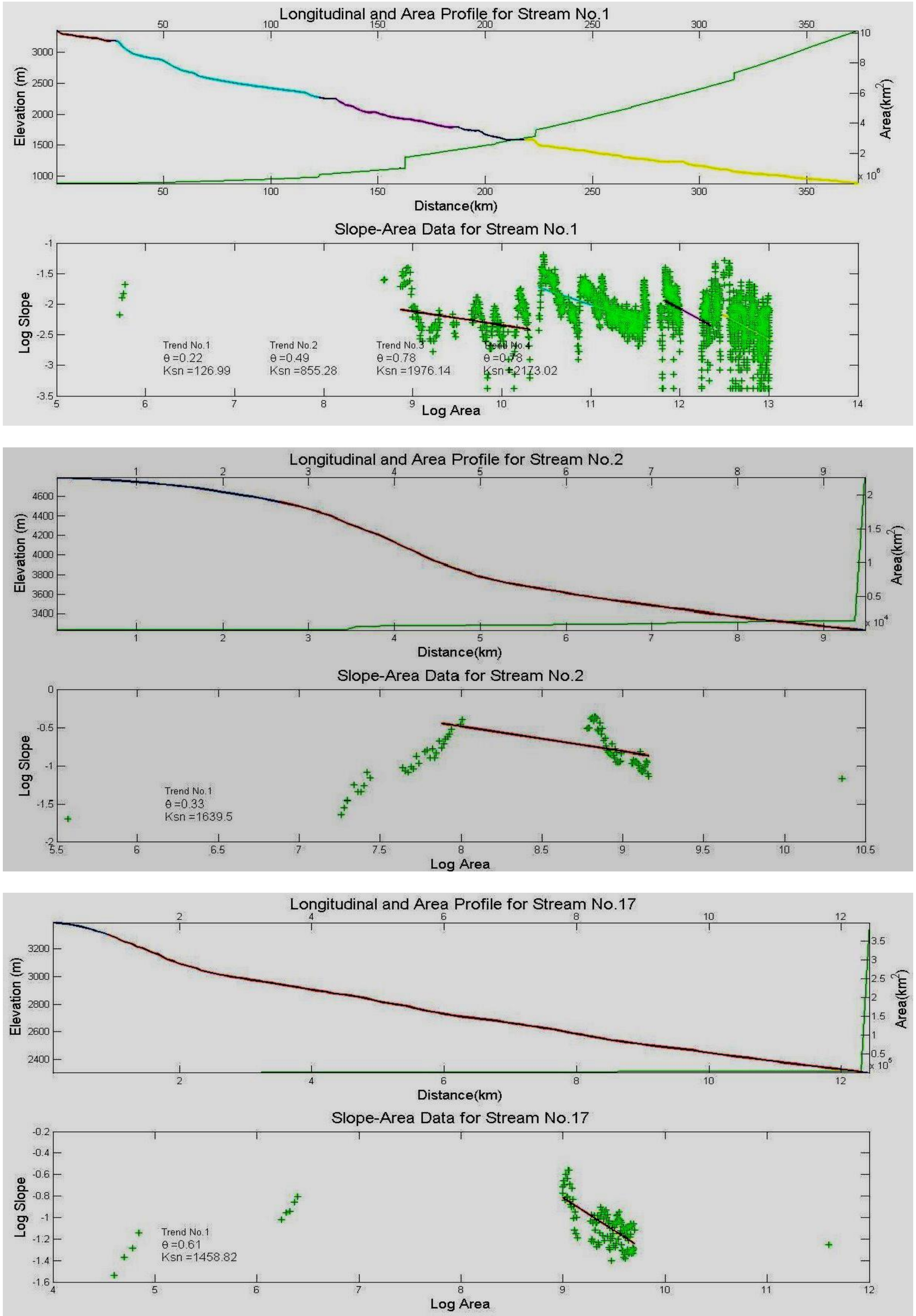
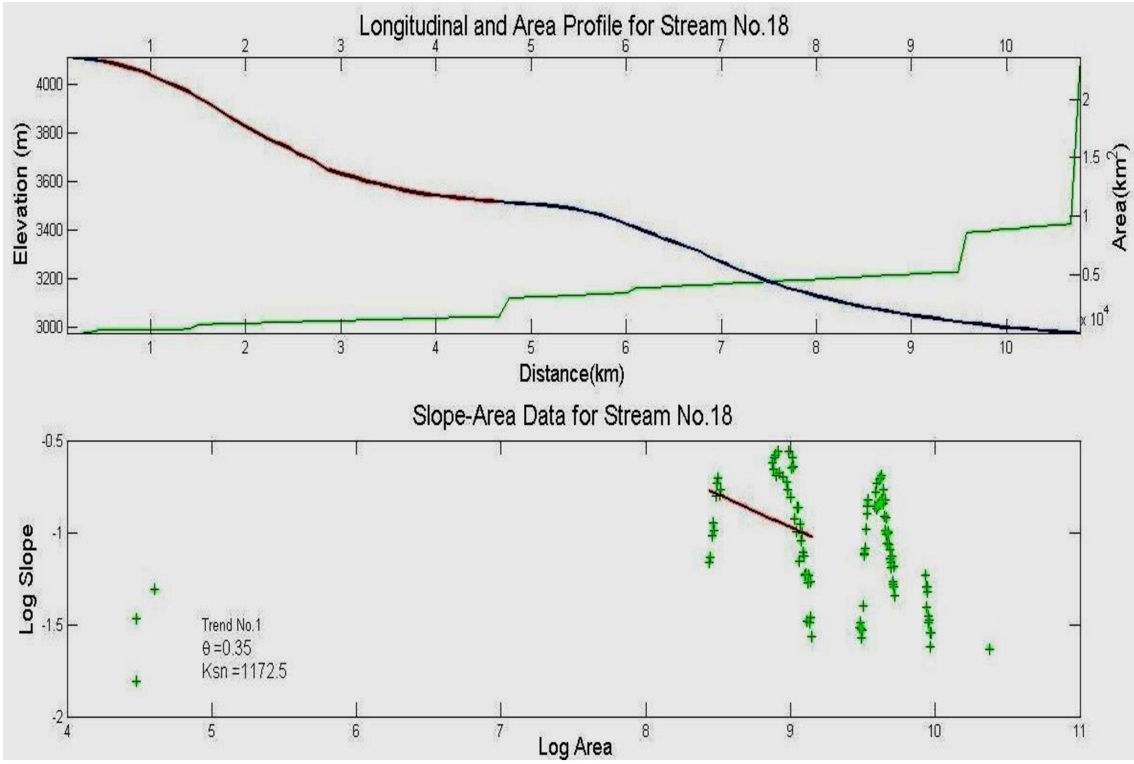


Fig 6-7-8: Diagrams showing river longitudinal profile, log area log slope profile with prominent nick points and best fit regression model.



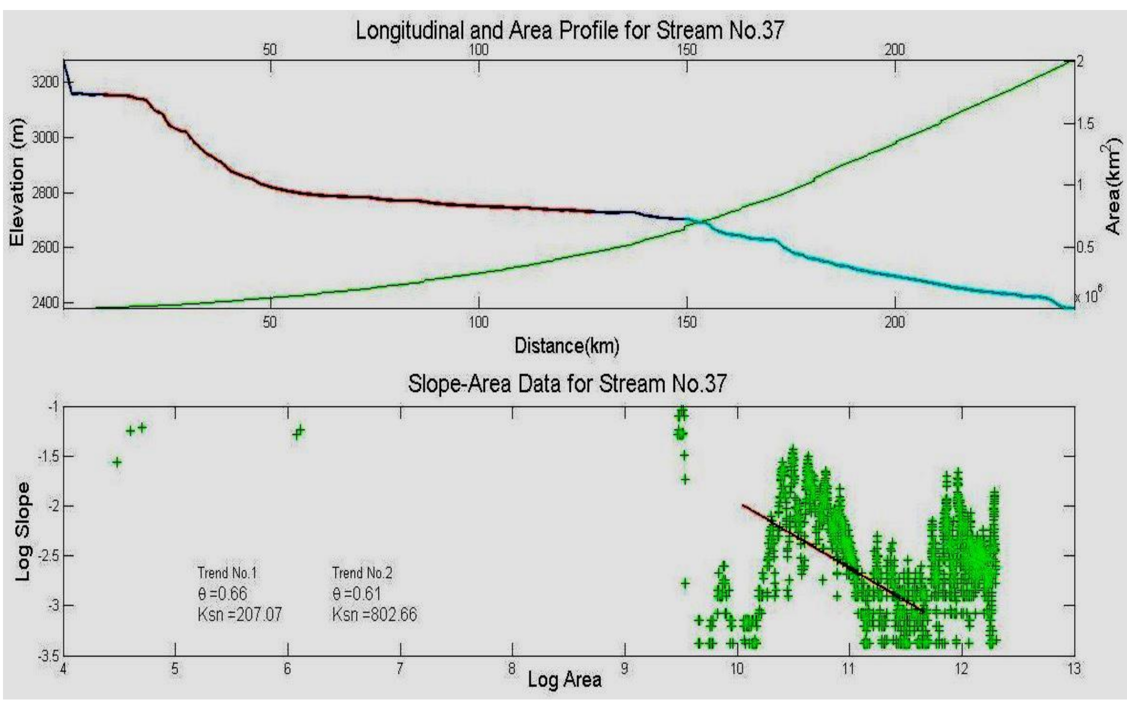
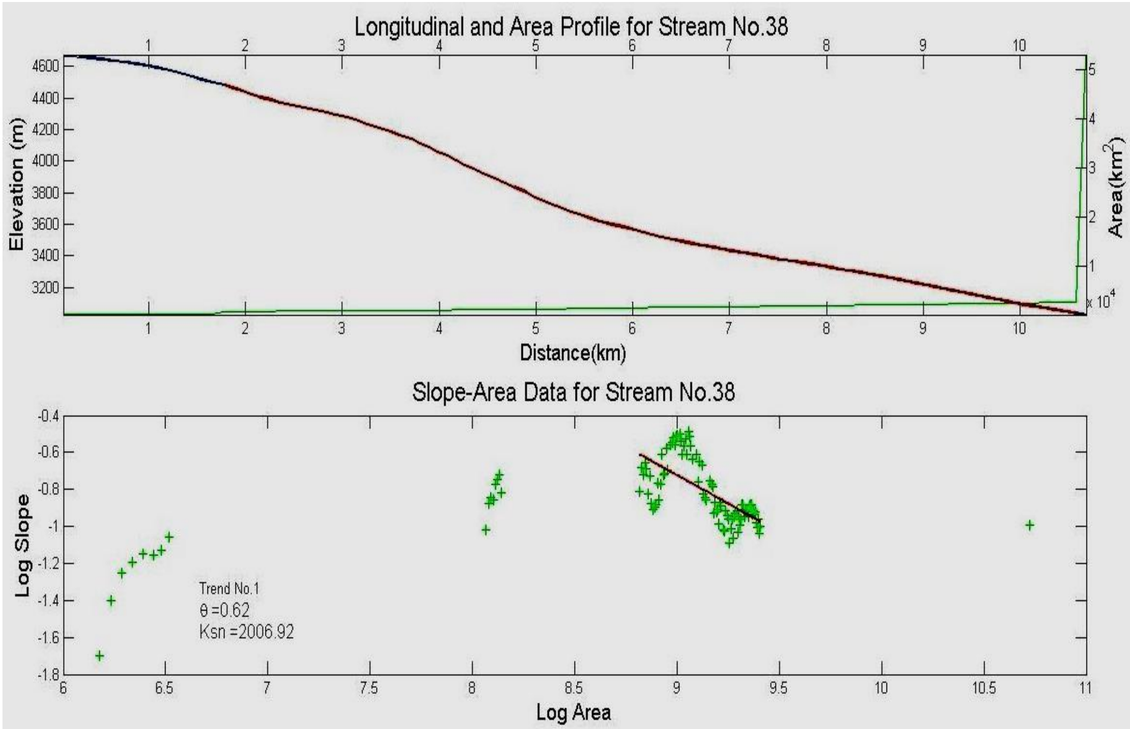


Fig 9-10: Diagrams showing river longitudinal profile, log area log slope profile with prominent nick points and best fit regression models.



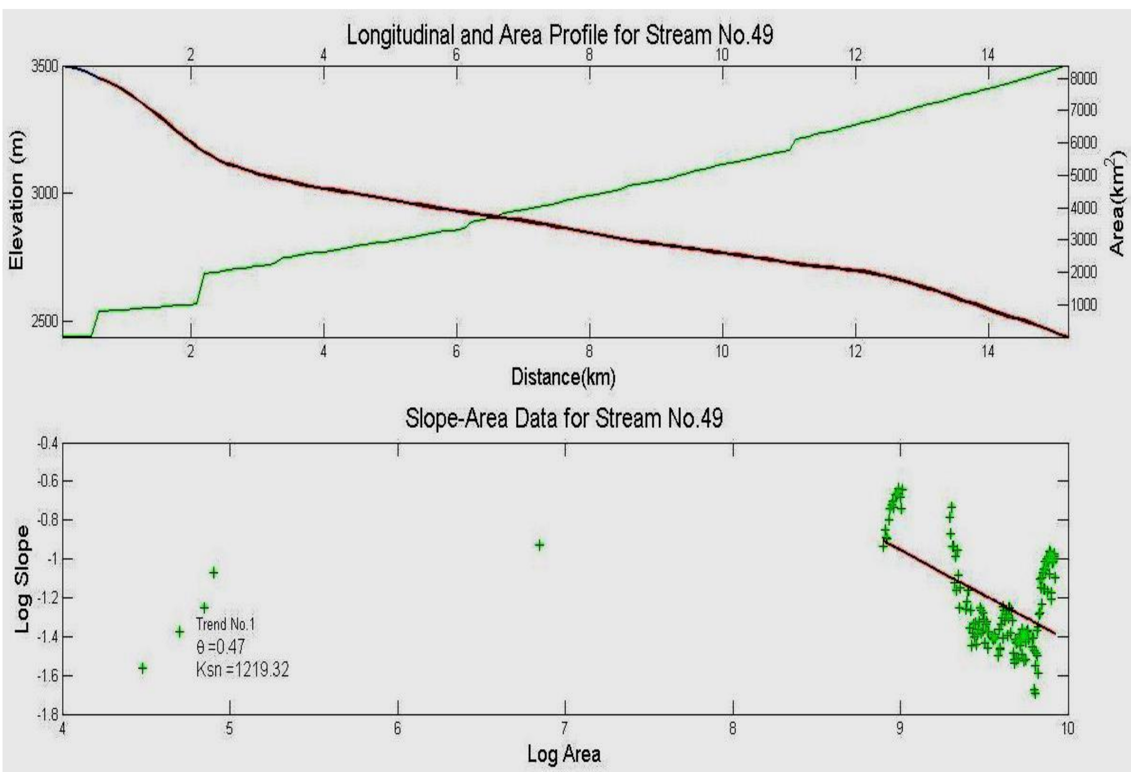
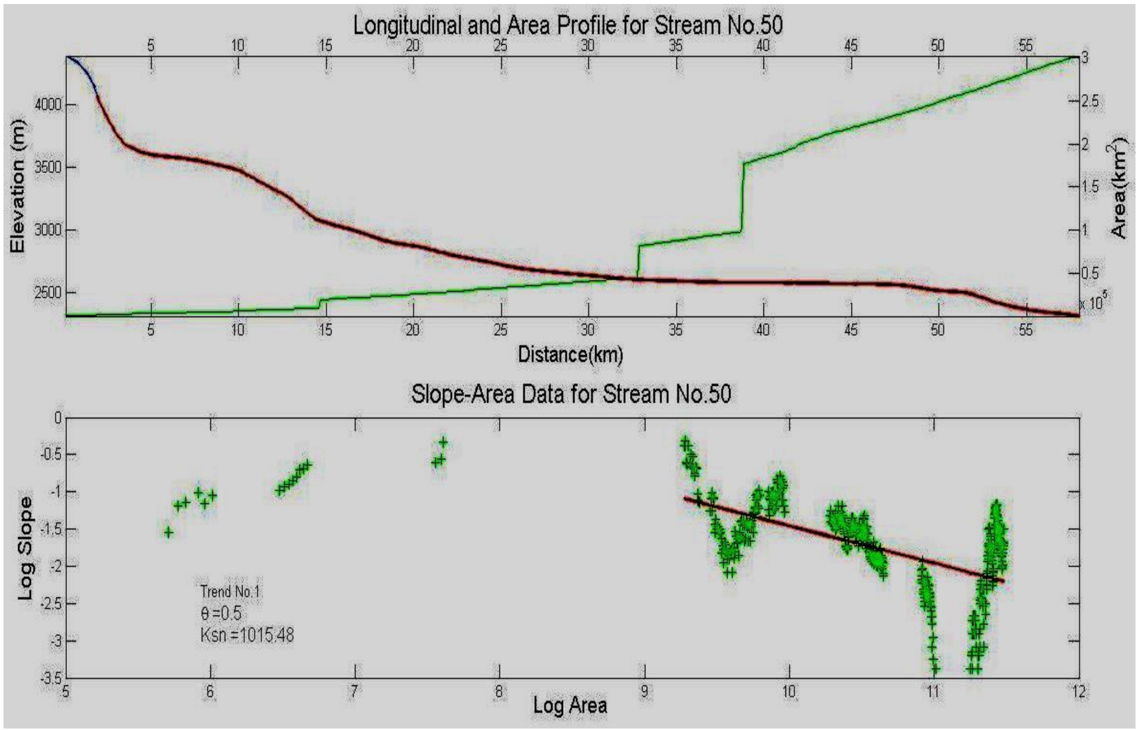


Fig 11-12: Diagrams showing river longitudinal profile, log area log slope profile with prominent nick points and best fit regression models.



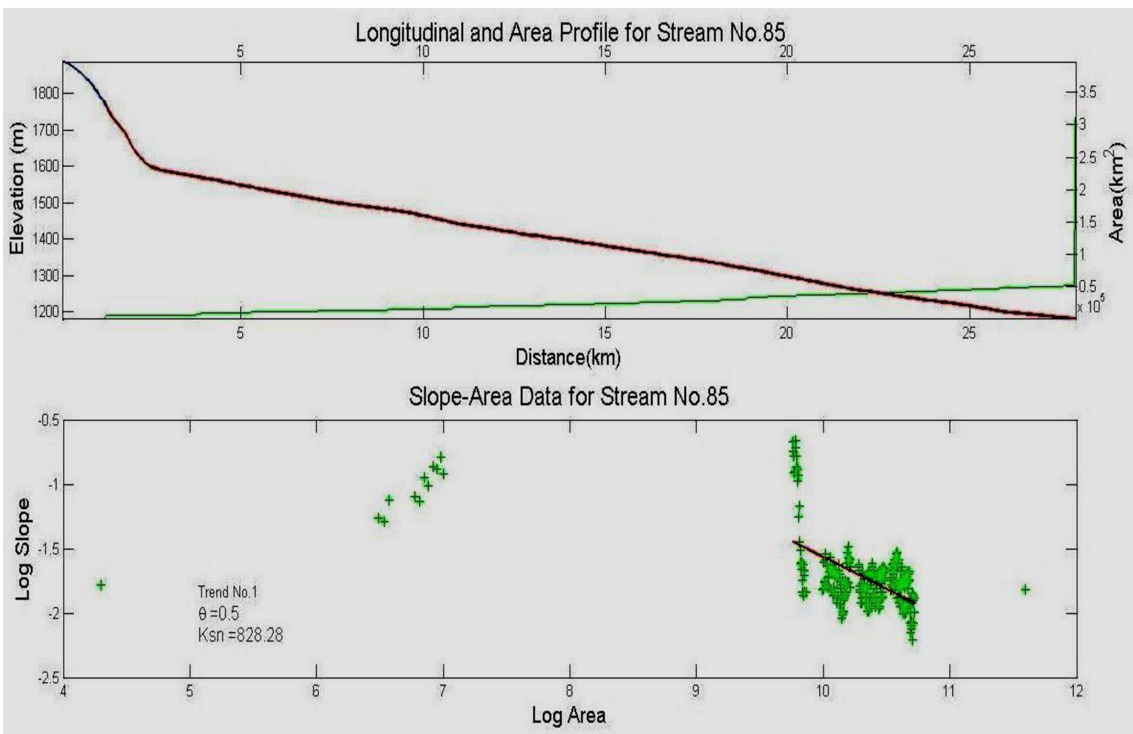


Fig 13-14: Diagrams showing river longitudinal profile, log area log slope profile with prominent nick points and best fit regression model.

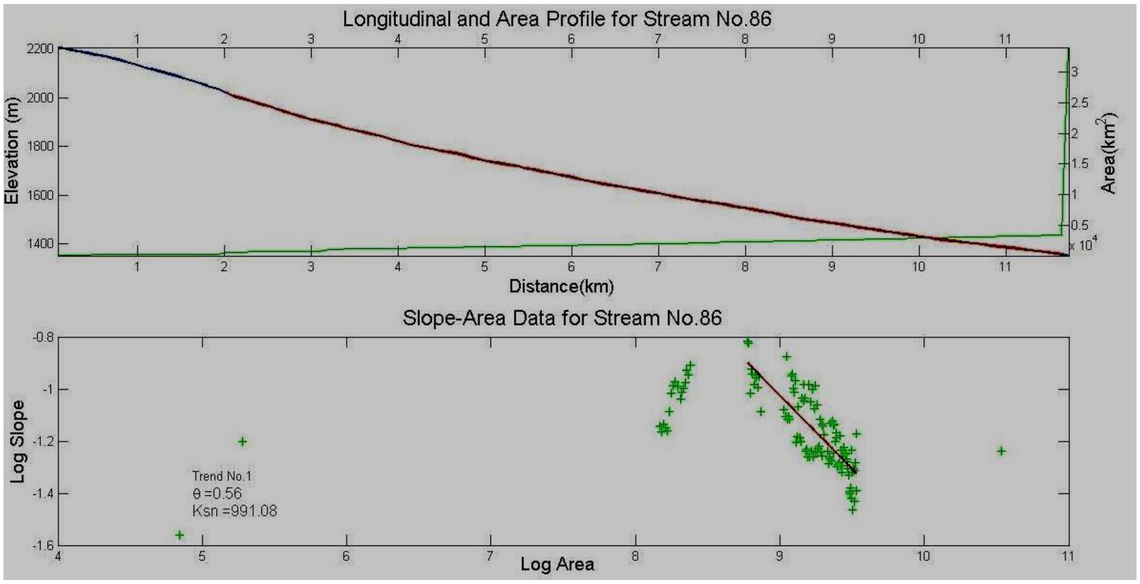


Fig 15: Diagram showing river longitudinal profile, log area log slope profile with prominent nick points and best fit regression model.

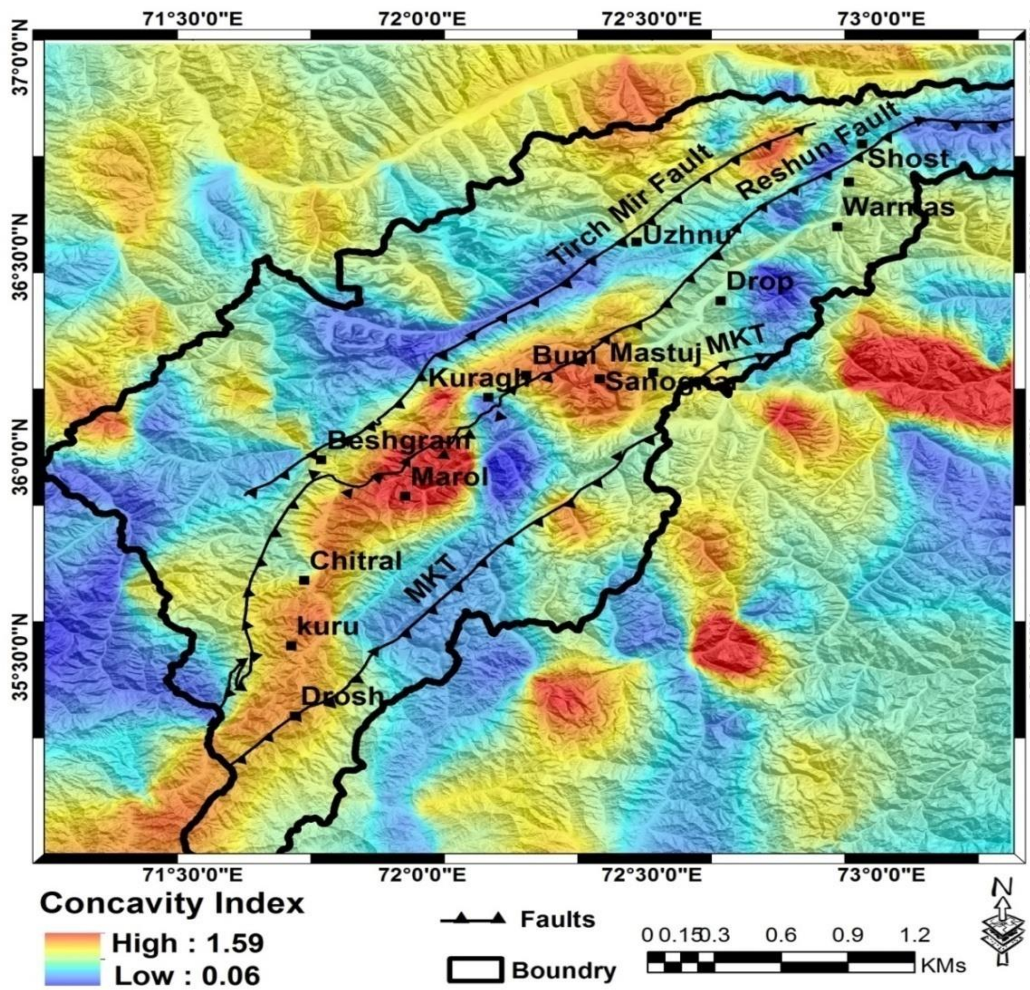


Figure 16: Map showing the concavity index of Study area.

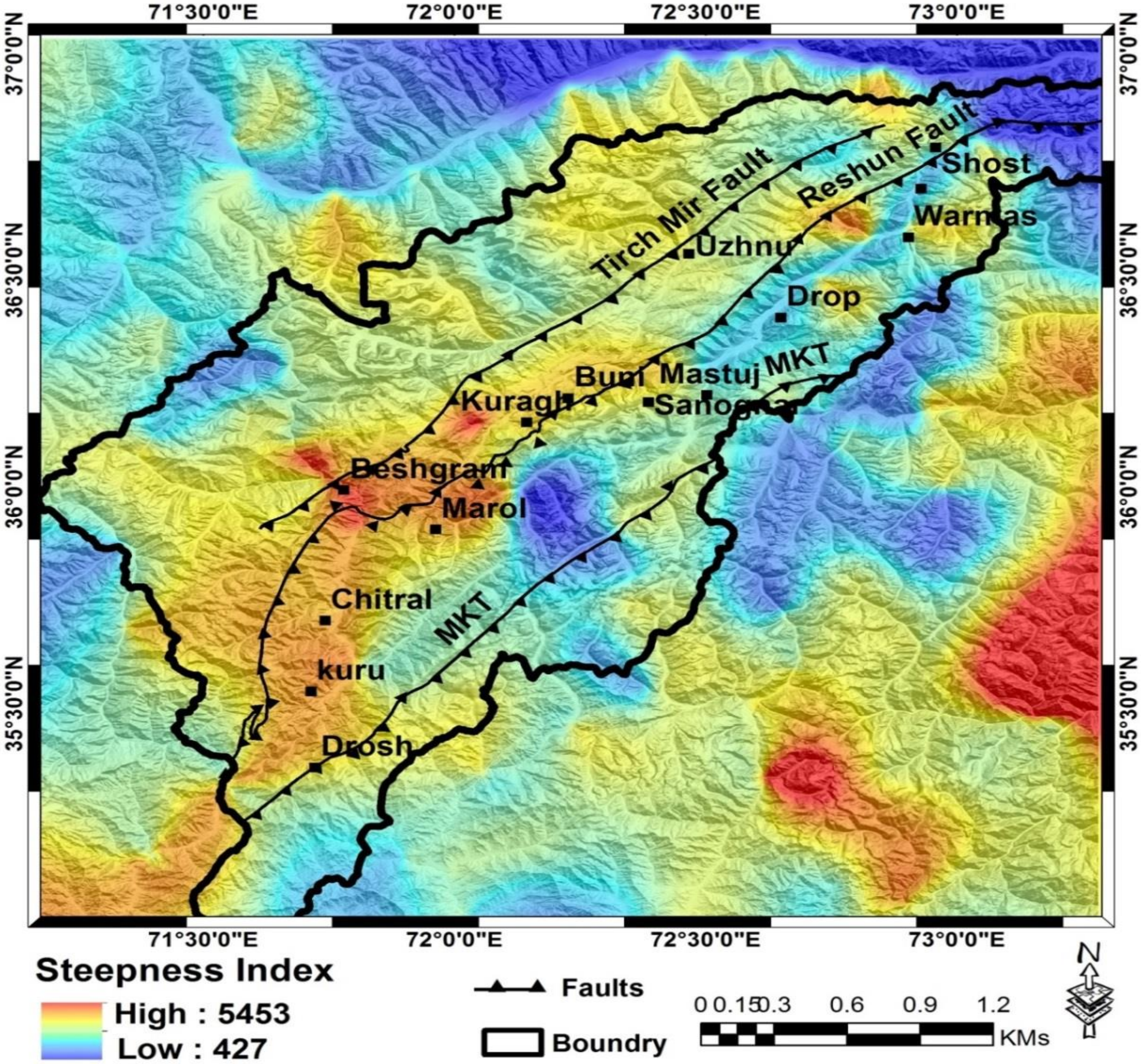


Figure 17: Map showing the Steepness index of Study area.

Steepness values of the study area are interpolated and shown in following map (Fig 17). Chitral district have both high uplift and erosion rates, but generally very steep slopes are not found there. Beshgram, Marol, Chitral, Kuru and Darost are the areas with high steepness values along the faults. As they are already interpolated in Fig 16, they have highly uplift rates too. But, we can see the high steepness value in highly eroded areas like Marol which means more uplift, more erosion and as a result we will have steep slopes.

As we already know that highly uplifted areas always have high drainage density, because of high numbers of small 1st order streams. As we move down words, number of streams reduced and volume of stream increased. That's why, major 5th and 6th order streams are always found in low laying plain areas.

In the following interpolated map,(Fig 18) high drainage density can be seen along the uplifted areas like Tirch Mir Fault, Reshun fault and MKT, as they are most tectonically active and highly uplifted areas. Low drainage density can be observed comparatively in areas with low altitude or with less uplift rates.

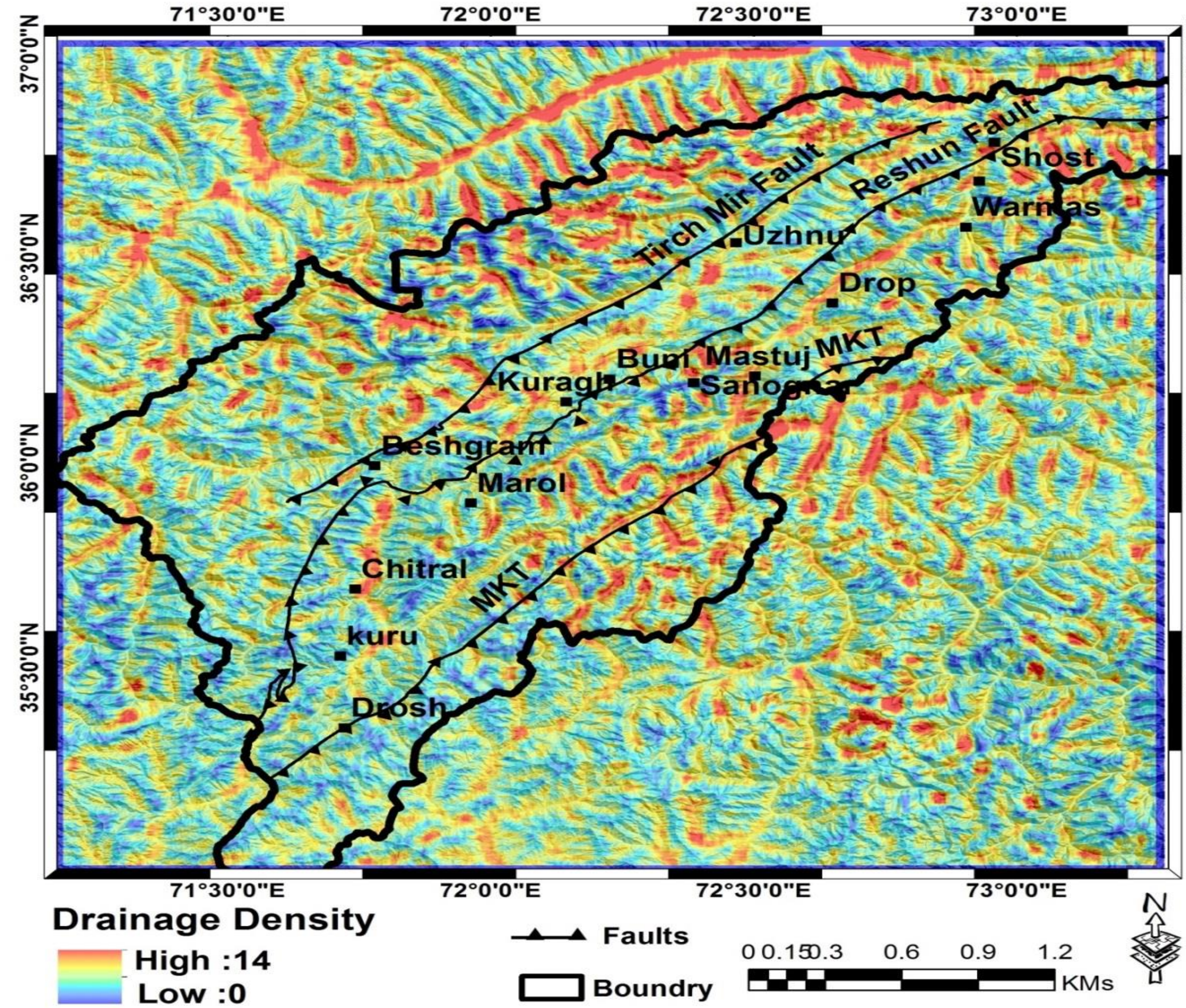


Figure 18: Map showing the Drainage Density of Study areas.

CONCLUSION

In this research it is proved that new technologies like remote sensing and GIS are the powerful tool for the investigation of Neotectonics.With the help of tectonic geomorphological analyses, stream profile analysis, determination of flow direction of streams and identification and calculation of knick points, tectonic movements have also been determined.

Streams of Chitral district are extracted with the help of stream profile analysis by computing there covered area and slope. Concavity and steepness maps showed that all the major features, especially the steepness and drainage network of Chitral district are totally tectonically induced.

Sanognar, Buni, and Marol are the ares wih high concavity and high erosion vales while Drop, Unzhnu, Warmas and Shost are the areas of low concavity and high uplift rates.

Beshgram, Marol, Chitral, Kuru and Darost are the areas with high steepness values. Marol and Beshgram are the highly eroded areas too, which means more uplift generates more erosion resulted as a highly steep slope.

Drainage density is also interpolated with the help of DEM and the result showed that Drainage Density is higher in uplifted areas as compared to low elevated areas. The uplifted areas are the MKT, Reshun Fault and Tirch Mir fault. Therefore, it is concluded that drainage network of an area is not only based on climate or geological factors but also well derived by tectonics.

REFERENCES

1. Pike, R. J., Geomorphometry-diversity in quantitative surface analysis. *Progress in Physical Geography*, 24(1): 1-20, (2000).
2. Tobler, W. R., Analytical cartography. *The American Cartographer*, 3(1): 21-31, (1976).

3. England, P., Molnar, P., Surface uplift, uplift of rocks, and exhumation of rocks. *Geology*, 18(12): 1173-1177, (1990).
4. Burbank, D. W., Causes of recent Himalayan uplift deduced from deposited patterns in the Ganges basin. *Nature*, 357(6380): 680-683. (1992).
5. Zavoianu, I., Morphometry of drainage basins. New York: Elsevier Publishers. (2011).
6. District Government Chitral. (2012) Chitral District Government Web PortlRetrived on April 10 2014 from www.http://chitral.gov.pk/
7. Hundreds of Original Projects for Employment (HOPE'87). (2010) Disaster Vulnerability Assessment Report District Chitral, KPK, Pakistan15 Aug. 2010 to 15 Sept. 2010. Retrived from *www.hope87.org/Documents/dvar.pdf*
8. Mahmood, S. A., Gloaguen, R., Appraisal of active tectonics in Hindu Kush: Insights from DEM derived geomorphic indices and drainage analysis. *Geoscience Frontiers*, 3(4): 407-428, (2012).
9. Howard, A. D., Kerby, G., Channel changes in badlands. *Geological Society of America Bulletin*, 94(6): 739-752, (1983).
10. Kirby, E., K. Whipple., Quantifying differential rock-uplift rates via stream profile analysis. *Geology*, 29 (5): 415-418, (2001).