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Socio – Political Context and Inferences from Remote Sensing in South Asia: A Study of Tectonic Induced Surface Deformation in SE-IKSZ

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ABSTRACT

Natural or man-made disasters are dreadful incidents that devastate lives, disturb the socio-economic and socio-political structure of a society and preserve or erase developments and gains based on decades, within few minutes. A catastrophe has the capacity to affect existing general population to their base, parting an occasion for self-investigation and reassessment of their framework and composition. This study signifies the Radar Digital Elevation Model centered pattern of drainage network to appraise the catastrophic landslide events due to the 2005 earthquake in Neelum-Jhelum Valley in SE-Indus Kohistan Zone north of Pakistan. This investigation highlights zones affected by the earthquake and vulnerable to landslides by utilizing Hypsometric integrals (HI values) and Hack SL-gradient techniques that are proficient in detecting erosion, land mass and tectonic movements. Dataset principally includes "Shuttle Radar Topography Mission (SRTM)" Digital Elevation Model having pixel resolution of 90 meters. Hypsometric investigation brings evidence related to the deformation periods of a geographical stage. To accomplish this objective, D8 method was used, 355 subbasins of 4th Strahler order, from 5th Strahler order 75 subbasins and from 6th Strahler order 15 subbasins were delineated. To appraise the indentations of erosional scarps, Hypsometric curves (HC) and Hypsometric integrals (HI) for all distinct subbasins were computed. Variable topographic elevations (Maximun, minimum and mean) were determined to decipher the HI values. The HCs are characterized as convex up, S shaped and concave down curves. Curvature of convex up symbolizes a lesser amount of eroded or deformed subbasins (comparatively young geography), and are located in conjunction of the North-Eastern anticline side of the Muzaffarabad that indicates the tectonic behavior of HKS, however S-shaped curvatures denote the transitional stage between the convex up and concave down deformational stage. The curvatures of concave down represents extreme deformation phase and are located west and eastern side of HKS.

Key Words: **SRTM DEM, HI, HCs, Surface Deformation and IKSZ (Jhelum-Neelum Valleys).**

Introduction

The October 8th, 2005 Kashmir earth quake includes some of the most conventional regions of the state of AJK and Pakistan, where the inflexible observation of Purdah, an isolation of the sexes, has dispossessed many females of schooling, medical-care, and their own way of livings. Conversely, because of the medicinal crisis that the earth quake grounded, the catastrophe has amazingly offered some females the prospect to request healthcare support for the very first time ever in their entire lives. Because of the the common need of rejuvenation in the earth quake affected regions, the majority of these communities, yet if they had a medical care assistance, have not at all been showing to state of the art medicines. For few, this altered in quick times of the quake, as local paramedics and doctors from Lahore, Islamabad, Karachi Peshawar, Quetta and international teams of medical specialists came forward in to place mobile medical units and camps in the worst quake-hit regions. Geological progressions constitute the active landscapes. These progressions are very convoluted as it comprises tectonic configurations and climatic influences. The era of Cenozoic is renowned due to the foundation of enormous topographical reliefs (Calkins et al., 1975). This high relief of topography was the development of the substantial striking amongst two significant continental plates, Eurasian and Indian tectonic plates (Molnar and Tapponnier, 1975; Anderson and Macgregor, 1998). The motion of Indian plate is counter clockwise in relative to the Eurasian. Many methods were implemented to evaluate the deformation rate, to mark this research successful. Distinction of the neotectonic zones is way significant footstep which facilitated to detect dynamic developments happening beside the northerly boundary of the colliding Indian plate. In addition to tectonic, climate is also essential parameter for the development of new geography. Indeed climate plays a dynamic role in landscape development. The unique features of the new landscape offer very vital evidence regarding temporal variations that take place on it. It gives advantages to replicate the earlier steps of the landscape expansion. This learning is keynote only for spatial characteristics but temporal traits as well. To discover tectonically dynamic part of the region, several flow orders of the streams are drawn and examined its pathway on diverse elevations and types of rock. Climate also plays a vigorous part shaping the development of land. As an observational factor climate acts as a vital role which govern the mechanisms of drainage system, deformation of tributaries, liquefying of glaciers, fluvial and wind erosion course. The Northing and the geography of zone are governing features of the environment. The degree of erosion depends on rock types, regardless of inflexibility and elasticity, the tectonic alteration and the lower water beds. These elements combine to shape a striking landscape (Baig MS, Lawrence., 1987; Bossart et al., 1988; Bossart et al., 1990; Abbott et al., 1997; Chen et al., 2003). The term Hypsometry is a healthy delineated computational technique used for height magnitudes of the earth's topography. Two eminent methods of hypsometry were applied .i.e Hypsometric

curves (HC) and Hypsometric integral (HI). Hypsometry demonstrates the land mass distribution at diverse elevation and gives reason behind such erosional movement. This detachment of land mass can be certainly perceived by Hypsometric plot. Hypsometric integral is quantitative measure of rate of erosion of any area. The region beneath the Hypsometric plot gives evidence about erosion, supplementary area under the curve shows eroded land mass. This type of terrestrial surface has U-shaped hypsometric plot (Wadia, 1931; Zeitler, 1985). The objective of this investigation is to address the automated DEM based drainage network to execute the natural geohazards assessment in SE-IKSZ (Neelam and Jhelum Valley) in Kashmir northern Pakistan. This research investigates regions vulnerable to geohazards from MATLAB based DEM derived hypsometric Integral values. Hack SL-gradient is also capable of identifying, tectonic and erosion induced topographic stages that may trigger mass movement.

The study area

The continuous uplifting progression shaped the largest mountain range well known as Himalayas (Wells and Gingerich, 1987). The massive collision between Eurasian and Indian plate is the result of this uplifting progression. It ranges 2,500 km in length and 160-400 km in width (Burbank, 1992; Burbank and Anderson, 2001). These assortments of mountain shield huge fragment of the Asia. This investigation mainly emphasizes the NW Himalayan portion that is situated in the region of Kashmir. Jhelum, Neelum and a part of Muzaffarabad city is spatially in this area. Muzaffarabad, capital of AJK, city Muzaffarabad is located on the panel of Neelam and Jhelum watercourses. Conferring to the geography of the range, that is typically hilly alongwith limitless carved subbasins. Jhelum and Neelam rivers drift analogous to one and other. However, current course of Jhelum watercourse strikes the Jhelum valley in southeast and northwest (Bull, 1991). The elementary motivation for selecting this region is its locality being in the neighborhood of Muzaffarabad Fault, Focal Frontier push. Numeral surveys exposed the vulnerability of these areas. The region lies in subtropical plateau and it is intensely inclined by the season of monsoon that roots landslide, heavy precipitation and flooding in this region. The devastating earthquake of October 8, 2005 extremely affected this region and its location is shown below in the Figure 1 below.

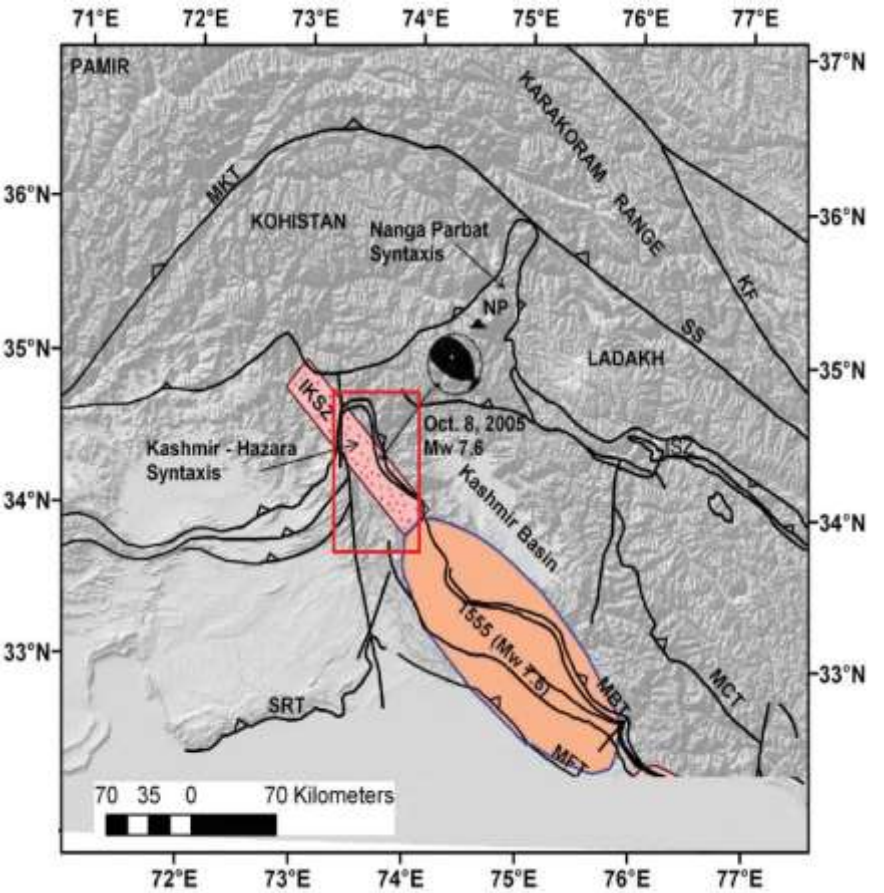

Figure 1. Tectonic location of the northwestern Himalayas highlighting October 8, 2005, Kashmir earthquake (Mw 7.6); colour-pinked areas representing IKSZ and projected rupture locations in 1555 Kashmir (Mw 7.6) and 1905 Kangra (Mw 7.8) earthquakes (after Bilham 2004; Avouac et al. 2006), Indus Suture Zone (ISZ); Karakoram Fault (KF); Main Frontal Thrust (MFT); Main Boundary Thrust (MBT); Main Mantle Thrust (MMT); Salt Range Thrust(SRT); Main Central Thrust (MCT); Main Karakoram Thrust (MKT); Nanga-Parbat (NP); Shyok Suture (SS).

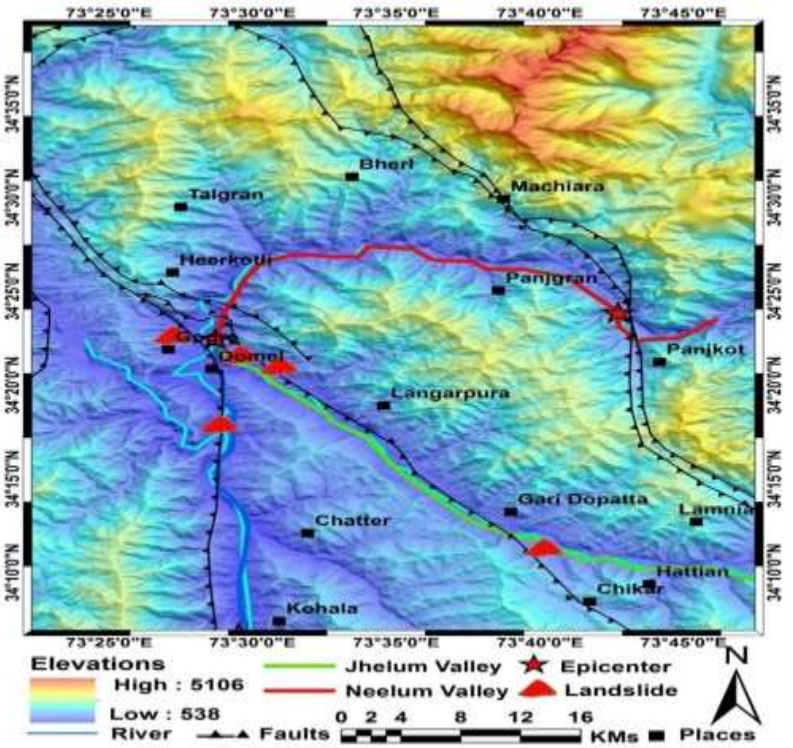

Figure2. Digital Elevation Model (DEM) of 90 m resolution of the Neelam and Jhelum Valley and adjacent region showing faults and main rivers.

Seismotectonic geological setting

Inordinate Himalayan Mountains are shaped by the sandwich joining of Eurasian and Indian plate. The curve of Kohistan is located in the middle of MMT and MKT. Himalayan curve is inducted from west to east, that is prolonged up to 2500 kilometer linearly and 160-400 kilometers in width (Kazmi and Rana, 1982; Kazmi and Jan, 1997; Whipple et al.1999; Whipple and Tucker, 1999). Namche syntaxes and Nanga Parbat, detach the trio components of Himalayan mount arch, the intervene is fundamental Himalayan array and to its right and left eastern Himalayas and western Himalayas are positioned correspondingly (Hodges, 2000). Opposite to right array of dominant Himalayas are sited in northern areas of Pakistan. The syntaxes of Hazara too is situated in this assortment that was the key reason of October 8, 2005 of the Kashmir earthquake. Our investigation marks on the south of MMT which back to minor share of the Himalaya. Other than MMT numerous other dynamic faults has also turned out to be the part of this exploration .i.e. MBT, Jhelum fault and MCT.

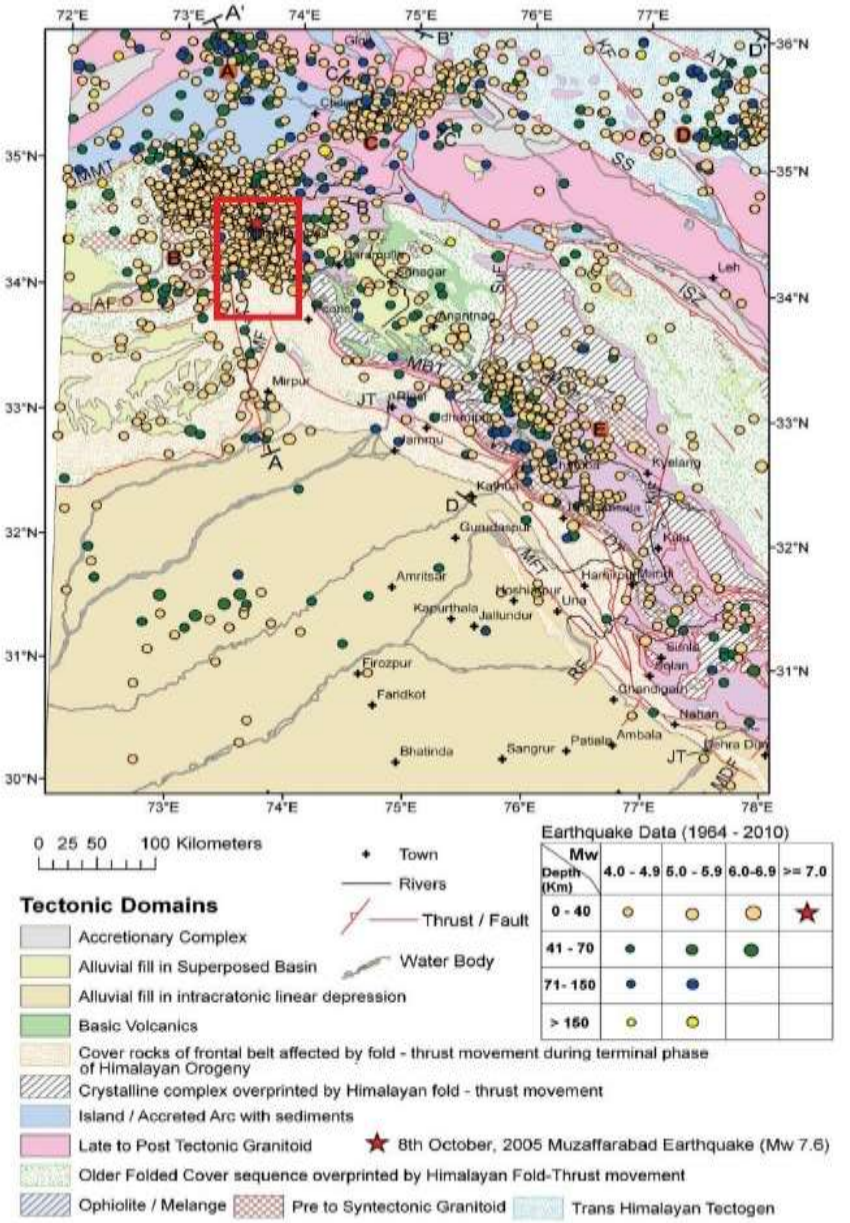

Figure 3. Digital Elevation Model (DEM) of 90 m resolution of the Neelam and Jhelum Valley and adjacent region showing faults and main rivers.

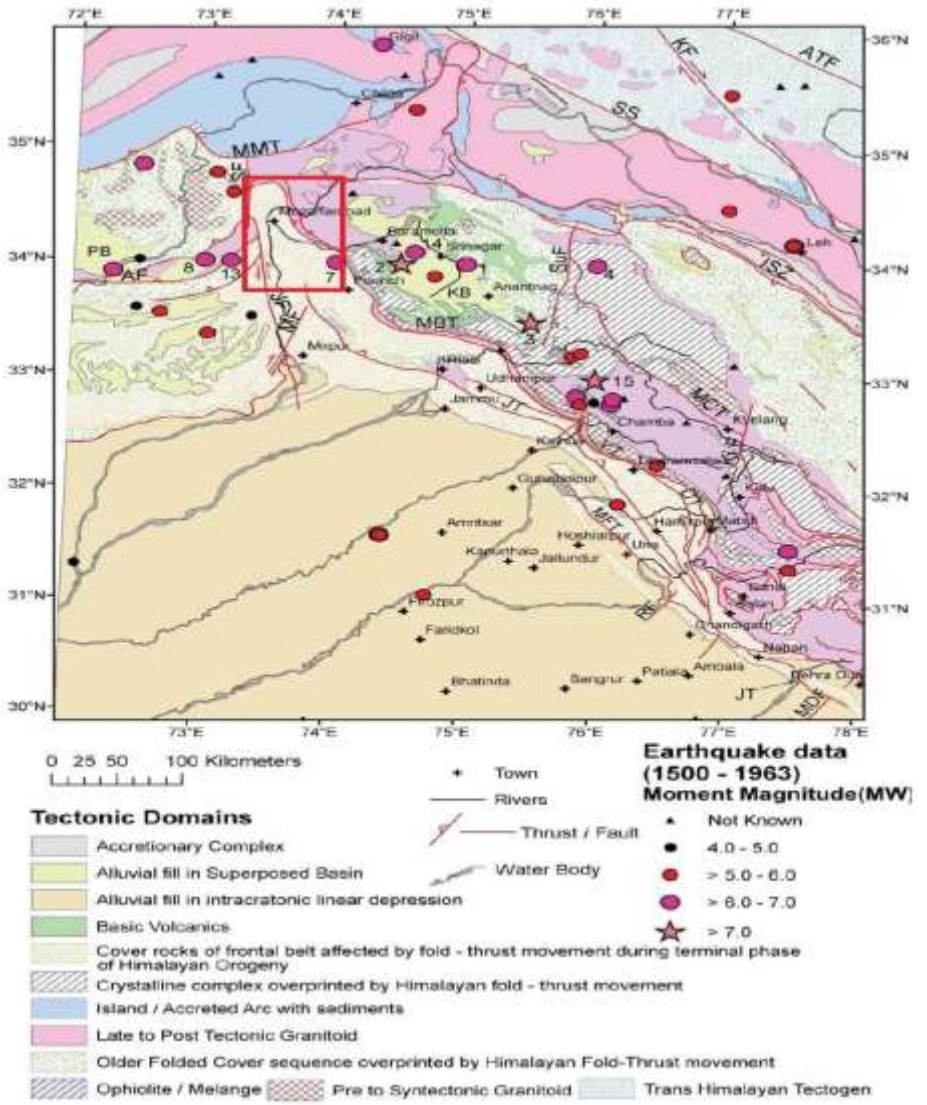

Figure 4. Diagram showing the geotectonic map.

Materials and methods

As a mandate to examine geonatural hazard valuations in Jhelum and Neelam valley we practiced RS data, vectorized Data (published automated faults, vectorized geological maps and Shuttle Radar Topographic Mission DEM etc. and correlated softwares. The data kinds used to focus dynamic tectonics mapping of Jhelum and Neelam valleys are

- Vector shape data

- Earthquake data
- SRTM DEM
- Published geological map

Table 1

Software used in the research are in the table below

Software Name	Application
ArcMap 10.3	For processing and mapping of GIS data
ENVI	Processing of Digital DEM
MATLAB (R2017a)	For the hypsometry and Hack Index
River Tools IDL	River Profile Modeling

Digitalized demonstration of the Earth's elevation is a DEM. It happens to be the utmost communal model used to illustrate the geography of land ranges. DEM created using Shuttle RADAR Topography Mission (SRTM) was exploited in the contemporary study. The methodology comprises hypsometric methods and Hack SL gradient index formed by produced DEM. The well-known D8 algorithm is the utmost frequently used method for approaching current directions on a topographic arises.

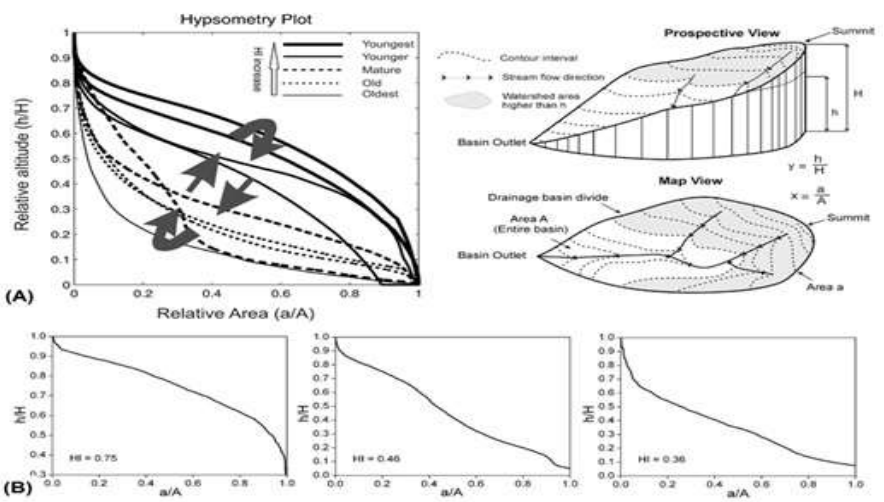

Figure 5. Schematic illustration of Hypsometric curve(HC) after (Strahler,1957).Geomorphics cycle showing changes in hypsometric curves(A),Convex up Hypsometric curve designates as youthful stage,S shaped curve and concave curve together with intermediate and low HI values are typical for mature and old stages (B).

In this process a 3x3 window is moved on entire DEM to analyze the flow direction from each pixel to one of its 8 adjacent pixels. For this purpose we first created sinks in data generated from the primary DEM. The "imposed gradients" techniques to decide flow track in surfaces (Surfaces are pixels that do not have a adjoining pixel with a inferior elevation), then we transformed this D8 flow network from raster to vector. Totally the pixels with flow encryption of zero are conserved as basin passage, which clinches the four culminations of the DEM and no statistics pixels in the DEM. This trajectory file generated stocks data for a solo basin or many split subbasins. Each subbasin has some characteristics including contributing area and relief. This trajectory file stocks all these characteristics for each subbasin. To fill and convert the DEM for compatibility in Matlab, we used River Tool 2.4, and two more vectors files were generated. Then the streams were categorized as 4th Strahler order, 5th Strahler order and 6th Strahler order (Figure 5). Then by using MATLAB different process applied to created final maps of Hack SL, Hypsometry and elevation to show mass movement concentration in the study area.

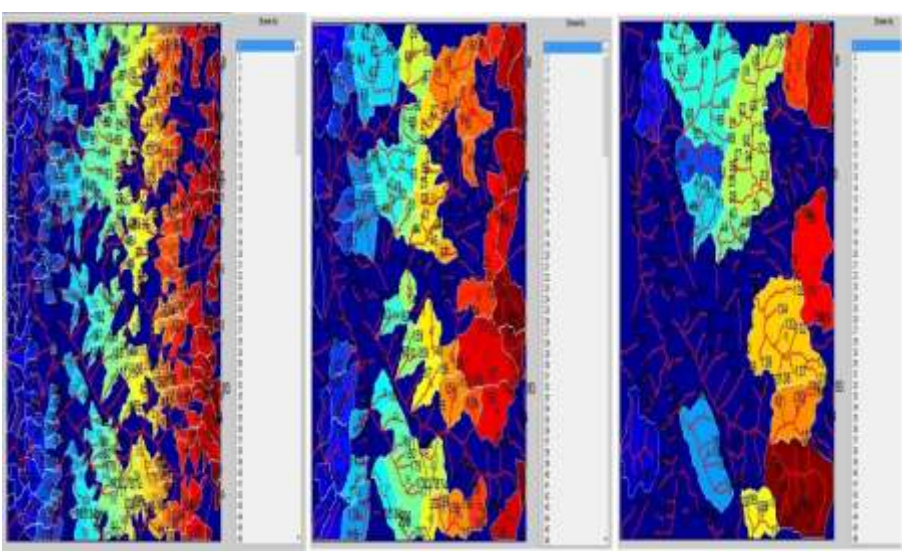

Figure 6. Matlab showing screenshots subbassins of 4th, 5th and 6th Strahler orders respectively. 355 Subbasins of 4th Strahler order, 75 subbassins of 5th Strahler order and 15 subbassins of 6th Strahler order.

Hypsometric curves and hypsomtric integral

Hypsometric evaluations were employed to assess diverse ordinary patterns of drainage basins and to delineate forms and proportions of diverse procedure that plays its role to outline the topography of earth on a time scale. HI is a unitless figure it benefits to equate diverse drainage patterns irrespective of the scale.

Hypsometric Integral can be calculated by

$$HI = \frac{H_{mean} - H_{\min}}{H_{\max} - H_{\min}} \quad (1)$$

The HI is commonly utilized to explain the eroded amount of a region under the HC or the behavior of a basin (Strahler, 1952). The HI values correspond to the raising and lowering of the topography with the passage of time (Figure 6).

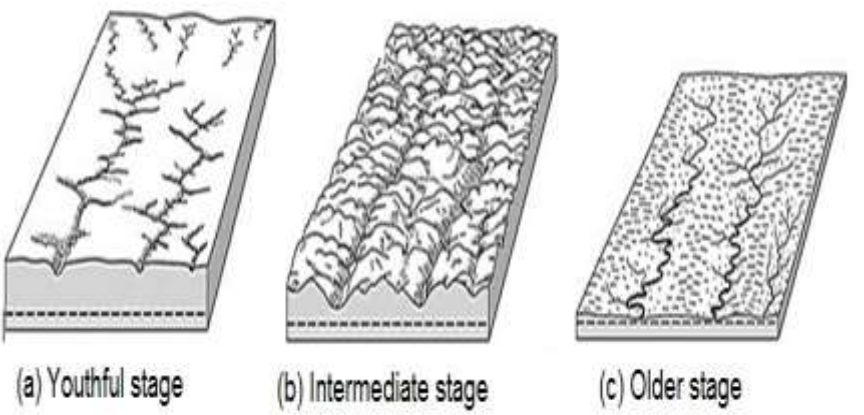

Figure 7. Different stages of Geomorphological cycle of topography ((a) Youthful (b) Intermediate satge (c) Older stage (William Morris Davis).

- HI ranges among 0 to 1. HI values congregated into 3 modules by means of admiration to the Hypsometric Curves
- Module 1 by means of U-shaped up hypsometric arcs (0.42 - 0.65)
- Module 2 by means of convex –concave hypsometric arcs (0.33 - 0.42)
- Module 3 by means of curved in hypsometric arcs (< 0.32)

The highest significance of HI specifies the fresh land sites and convex-up is its curvature character (Figure 4 (a), possibly formed by neotectonic regions. In accumulation to curvature, highest significant Hypsometric Integral value advises the inclination of the range. Higher Hypsometric Integral values are associated with undeveloped dynamic regions of tectonic (Small and Anderson, 1995; Keller and Pinter; 1996).

Hypsometric arc is a plot between relative elevation and relative area of the given basin. The fraction hypsometric arc (area-altitude arc) relates horizontal cross-sectional range of a drainage basin to comparative height above basin opening. (Arthur and Strahler**)** (Figure 4 (b).

The curvature of S-shape is intended for developed topography and concave up is the third Hypsometric Curve with the lowermost Hypsometric Integral designates mature lands. Using Eq. (1), calculated Hypsometric Integral values for individual catchments are classified into 3 modules on their curve contour (Figure 7).

Stream length-gradient index (Sl-Index)

River arrangement attains a steadiness categorized by concave contours (Schumm et al., 2000). The abnormality of any river from stability may be due to tectonic movement, Petrology influence and weather factor (Burbank et al., 1996; England and Molnar; 1990). Hack Scientist was the first, who worked on it and defined an index in 1973 to study the influence of the ecological parameters on river profile (Hack, 1973; 1975). Mathematical expression for the index is as follow (Eq.2)

$$SL = \left(\frac{\Delta H}{\Delta L}\right) L_t \qquad (2)$$

In this expression, ΔH represents in altitude and ΔL represents length. At this point this is the distance reach, and the distance horizontally amounted from the watershed division to the epicenter of the range is denoted by Lt. This comparative dynamic tectonics is deliberated using the SL directory (Keller and Pinter, 2002) (Figure 7). The modern active tectonics is characterized by spineless rocks with a great SL index.

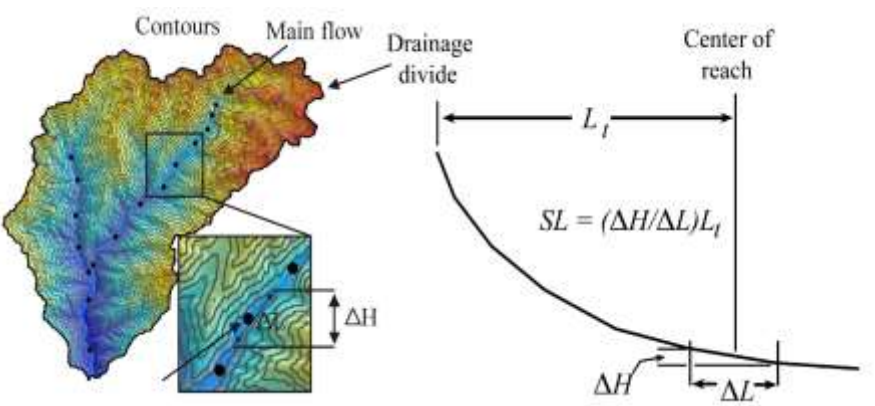

Figure 8. Mechanism of computation of Hack stream-length gradient index.

Results and discussion

Geomorphic catalogues as well as hypsometry and Hack stream span slope indices be the elementary factors contributing the knowledge concerning local enrich, native topographic elevate and oblique reasoning of chaos in the entire constituency.

Researchers are attempting for an affiliation among climatic variations and the tectonic developments. Presently, the race amongst deformation proportions and climate variation has motivated experts to pay plenteous attention. (Molnar and, England, 1990).

In order for testing the petrology, strong point of tectonics and the influence of atmosphere on landscape development, hypsometry plays a vital role and is also a commonly utilized tool. It demonstrates the distribution of diverse altitudes surviving in a watershed. Geomorphic figures have the capability to locate the standards of HI and HC's usefully through DEM (Perez-Pena,, 2009). Numerous solicitations together with morphometric investigations of Mars, potency regarding the tectonic engagement, captivating power of glaciated range above hypsometry and diverse phases of enlargement of drainage watersheds are implemented by means of such procedures, but still encounters in Hypsometric Integral individuality values are there. The rate of HI is intensely reliant upon the dimensions of the watershed, watershed height and area contributed by the watershed.

Nonetheless, it is remarkable that there are arguments related to distinctive Hypsometric Integral. Summerfield and Walcott (2008) did not have fitting together trapped amongst catchment measurement (relief of Watershed and its area) and HI in the southern-east sideline of South Africa. Cheng et al. (2012) deliberated Taiwan mount array and designated that landscape in stable condition and it is reliant on scale where the landscape's topography is in nonaccessible form, (Mahmood and Gloaguen, 2011), Hafsah et al., 2013).

Consequences of the investigations defines that Hypsometric Integral values are reliant on tectonics, petrology, scale and climate in order to compute HI through lattices numbers other than that of watershed that represents gradient of variation in the altitude inside each pixel but it do not represents the degree of examination.

In Pakistan's region of Azad Jammu Kashmir zone, Jhelum is the dynamic region seismically for which 4th order of hypsometric integral values are extracted. Eurasian and Indian plates are colliding in the area with cruel past of tectonics movement situated in inferior dominion Syntaxis of Hazara Kashmir. Central level of Tectonics fluctuate by reason of faults crusade and deviation in the happening's of tectonic level. During this research, we used SRTM DEM with a Spatial Resolution of 90 meters which is at liberty accessible and designated features of HI to discover Plates implication.

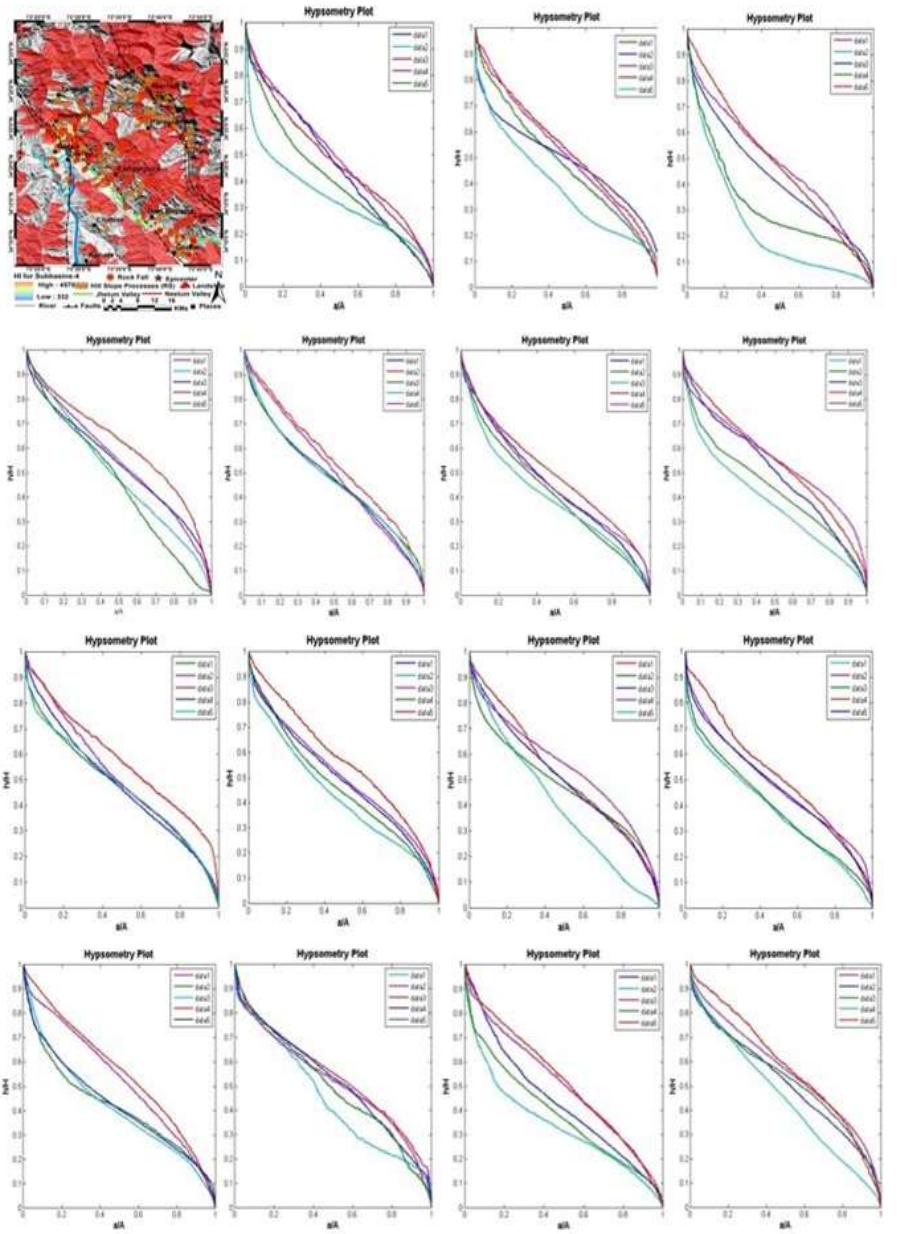

Figure 9. Illustration showing map and Hypsometric curves for the subbasins of order 4.

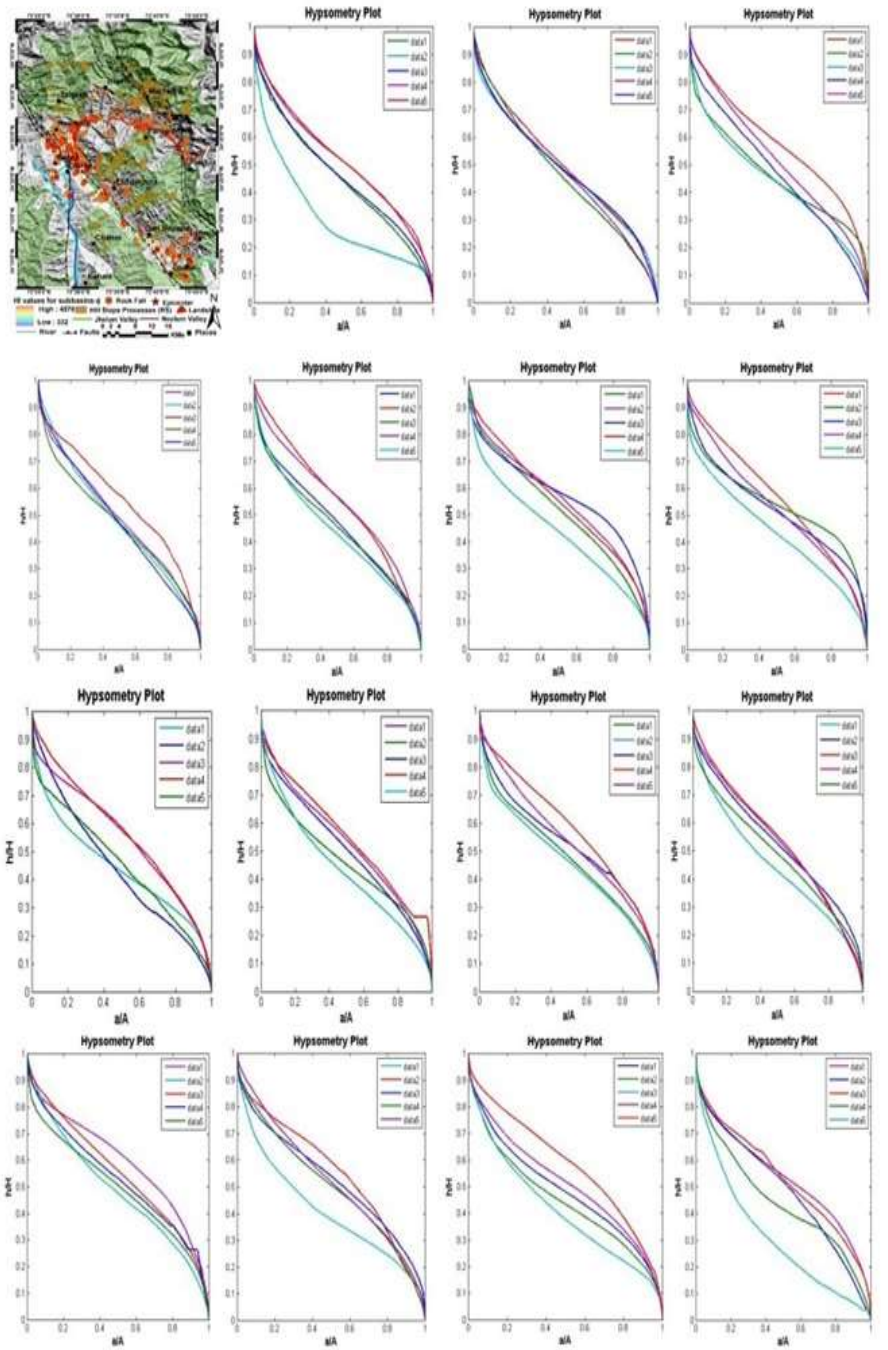

Figure 10. Illustration showing map and Hypsometric curves for the subbasins of order 5.

Concentration of mass movement in respect to the aspect of slope

Several rising aspects similar to soil conditions and land cover, isolation and climatic disorder have severe possessions on the activities of topographical features. The course of the movement of topographical features in the research area is situated in the southeast and southwest deliberated by DEM. The investigation discloses that approximately 57% movements of entire topographical features is in the southeast path that is almost 38% of research zone. The bulk displacement from 24% is in north direction and 31% of the region is along eastern direction. The movement in opposite to north direction conserves great range in comparison to the supplementary directions, which confirms that this positioning of the shift of mass is subjugated in southern position which might be present in line for the geometrical conditions and nature of topography.

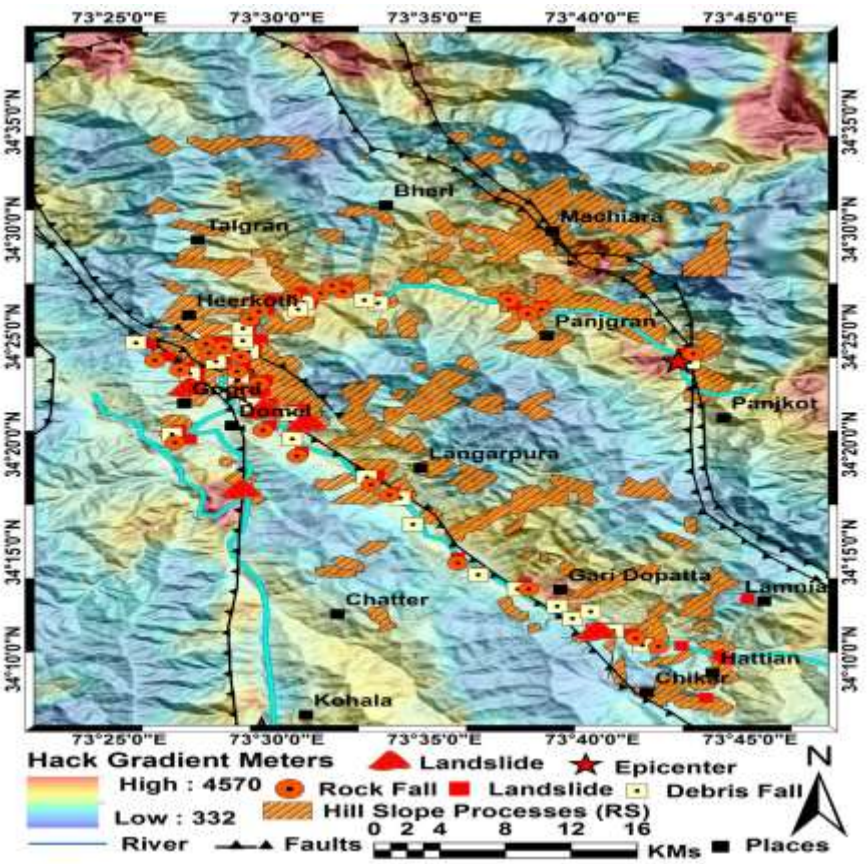

Fig 11.The Hack gradient map with all the parameters like rock slides, debris fall, landslides and active hill slope processes.

Concentration of mass movement in respect to the funtion of elevation

The area of research comprises of valleys that are in deep and extremely saturated mountains that series from 500-800 meters height in the southern pm1 and 1999.5-4499.5 meters higher in the northern fragment from the sea level. The region amongst height of 500-l4OO meters that consists of basins those are in depth and the terraces though the region from 1500-2200 meters comprises of wreckage cover and vertical gradients. 74% of whole movement of mass is lower than 2000 meters from the mean sea level and the remaining quarter is within 2000-3000 meters. This examination tells that approximately 74% of the movement of mass is amongst 1000-1500 meters raised up areas of mountains. The presence of prior bulk movement is preferred in initiating movement of topographical features throughout a seismic activity is proficient in the study of Langarpura and Neelidandi rock plunge. However, examination of Panjgran decline revealed that bulk displacement is the consequence of already existent dispositions sited destabilized by Neelum Tributary.

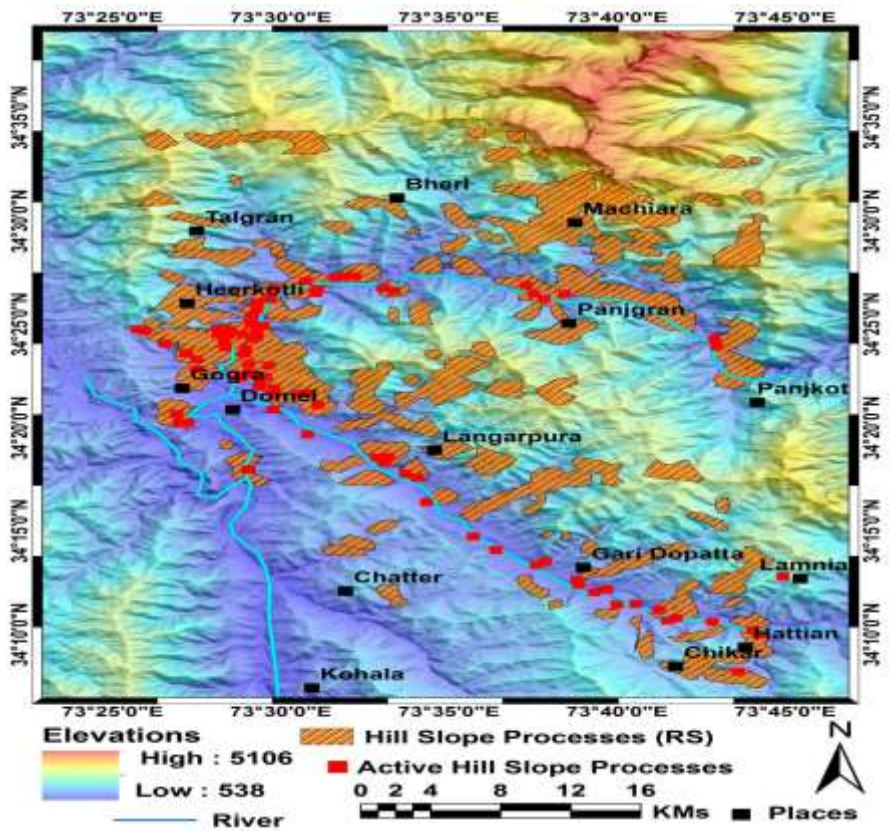

Figure 12.The diagram shows active hill slope process location.

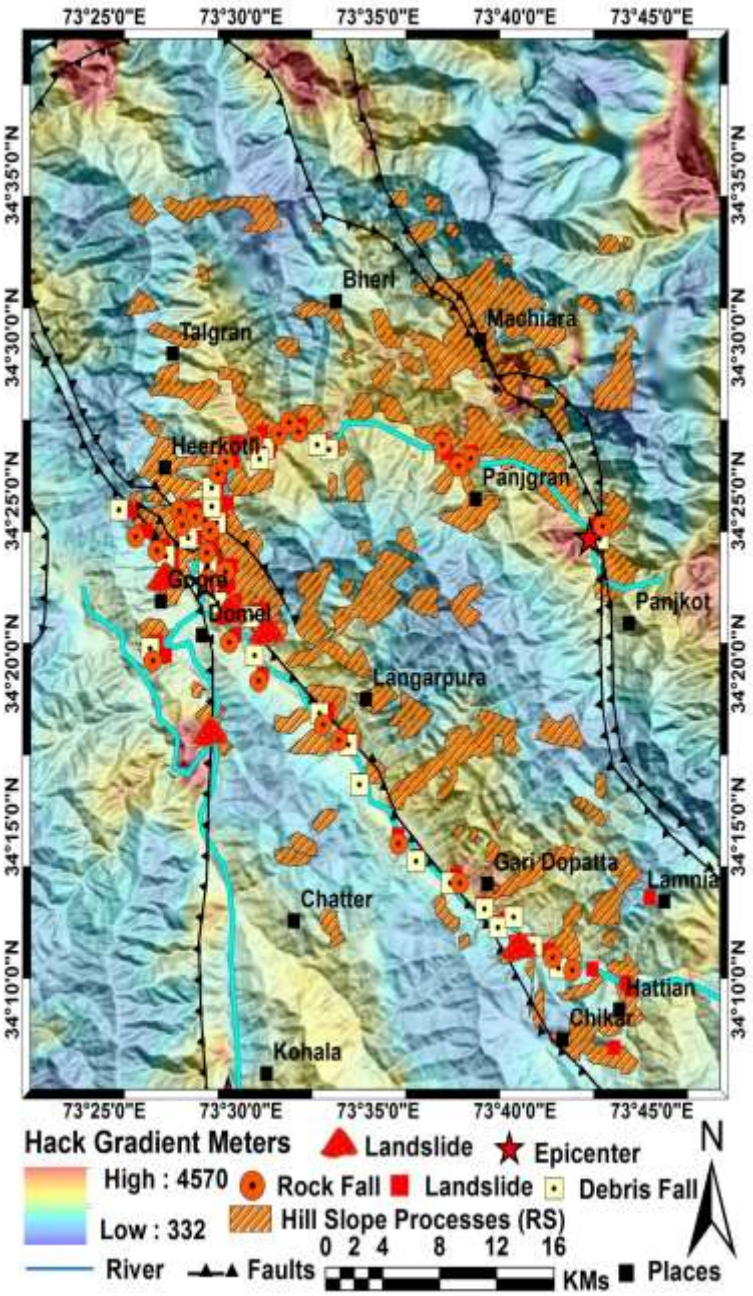

Figure 13.The diagram shows active hill slope process locations.

Figure 14. The remote view of deformed fluvial terrace surfaces at Chehlabandi, north of Muzaffarabad. View northwest. A getaway of numerous terrace surfaces with rising height to the west (T1–T6) are all rapidly shortened by an east–west-trending fault indicated by red line. (After Keneda et. al., 2008).

Figure 15. Surface rupture across valley floor of Sehli Katha, Looking east. A getaway of two low terrace surfaces (lower and upper surfaces) of likely Holocene age are deformed in addition to the modern riverbed.

Conclusion

The deadly earthquake of Muzaffarbad Mw 7.6 in 2005 was also linked by an approximately 72 km long northwest-directing topographic crack with a vertical division up to ~6-7 m. DEM based Mapped topographic rupture outline demonstrates that neither MBT nor MFT is accountable for this event, but active fault segments of SE-IKSZ, jointly named as Bagh-Balakot fault system further connected to the basement faults linking with the IKSZ. The Bagh-Balakot fault segment of IKSZ was the first precedent topographic-cracking earthquake in the sub-Himalayas, but the largely destructive known earthquake in history of the region. Our DEM based hypsometric and hack gradient results are consistent with the possible for destructive topographic rupturing north of the MFT and there is a need for a research in this region for evidences for neotectonics. It is also observeed that rigorous structural damages were completely found on the hanging-walls of plane of the topographic surface crack that may be a collective consequence of abnormally peak ground movement and widespread tectonic surface deformation. This seismic event is unique in a sense that its epicenter is in north of Muzaffarabad but its source lies in IKSZ. The remote sensing and GIS based techniques are semi-automated, quick, proficient and accurate for the delineation of deformed zones in contrary to longer term, costly and conventional surveying techniques.

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